

# PHYSICS & SOCIETY

A Publication of *The Forum on Physics and Society* • A Forum of *The American Physical Society*

## Editor's Comments

We have a wide variety of interesting articles for this edition of *P&S*. To open, we have a number of items of Forum news: Election results are in; we extend congratulations to those individuals elected to the Executive Committee and thanks to all candidates who ran and to the members of the Nominating Committee for their good work. Congratulations are also extended to the recipients of the Forum's prestigious Burton and Szilard Lectureship awards and to members of the Society who have been elected to APS Fellowship through Forum nominations. We present a summary of FPS-sponsored or co-sponsored sessions that will occur at the upcoming Washington, DC and Portland meetings. As we related in our October edition, APS Council established an ad-hoc committee to examine the Society's climate-change statement. This committee, chaired by Dan Kleppner of MIT, has now submitted its report. The committee recommends that Council reject the petition and that the current statement be allowed to stand, but also requested that the Society's Panel on Public Affairs (POPA) examine the statement for possible improvements in clarity and tone; we reprint an APS web release describing this situation in further detail.

As evidenced by letters received from two foreign correspondents, the issues of climate change and nuclear power continue to engage our readership: a correspondent in Sweden writes to raise issues with Dave Hafemeister and Pete Schwartz's tutorial in climate change that ran in our July 2008 edition, and our articles on the medical isotope issue and the Canadian Nuclear Waste Management Organization generated two contributions from a correspondent in Canada. In a related development that occurred just as our October edition went to press, an AIP FYI reported that the Subcommittee on Energy and Environment of the U.S. House Energy and Commerce Committee was considering legislation to provide federal assistance for the development of molybdenum-99. A later FYI (November 18; <http://www.aip.org/fyi/2009/138.html>) reported that the House of Representatives had passed the bill, H. R. 3276, by a vote of 400-17. This bill would authorize, from FY 2011 through FY 2014, expenditure of \$163 million for the establishment of a program at the Department of Energy to support industry and universities in the domestic

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# FORUM NEWS

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## Executive Committee Election Results

In an election that closed on November 13, 2009, 15.5% of the FPS membership (940 members) cast ballots. The following individuals were elected to the Executive Committee from a strong slate of candidates, and will formally occupy their positions beginning at the end of the upcoming “April” meeting. Congratulations to:

*Vice-Chair:* Pushpa Bhat    *Secretary-Treasurer:* Benn Tannenbaum    *Members-at-Large:* Lea Santos & Richard Wiener

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## 2010 Forum Award Recipients Announced

Recipients of the Forum’s Joseph A. Burton and Leo Szilard Lectureship Awards for 2010 have been announced. The Burton Award is given to recognize outstanding contributions to the public understanding or resolution of issues involving the interface of physics and society. The co-recipients for 2010 are **Abdul Nayyar** (Sustainable Development Policy Institute, Islamabad), “For broadening the public understanding of science in Pakistan and for informing the public of the dangers of the nuclear arms race in South Asia,” and **Pervez Hoodbhoy** (Quaid-e-Azam University, Islamabad), “For broadening the public understanding of science in Pakistan and for informing the public of the dangers of the nuclear arms race in South Asia.” The Leo Szilard Lectureship Award is given to recognize outstanding accomplishments by physicists in promoting the use of physics for the benefit of society in such areas as the environment, arms control, and science policy. The 2010 recipient of this award is **Frank von Hippel** (Princeton University), “For his outstanding work and leadership in using physics to illuminate public policy in the areas of nuclear arms control and nonproliferation, nuclear energy, and energy efficiency.” P&S extends hearty congratulations to Drs. Nayyar, Hoodbhoy, and von Hippel on their well-deserved recognitions, and extends thanks to the members of the selection committees for their diligent work (Burton: P. Podvig, Chair, R. Jeanloz, P. Lewis, V. Thomas; Szilard: P. Podvig, Chair, R. Jeanloz, P. Lewis, V. Trimble).

The deadline for nominations for the 2011 Burton and Szilard Awards, as well as the Forum’s Nicholson Medal for Human Outreach, is July 1. Information on Forum prizes and awards can be found at <http://www.aps.org/units/fps/awards/index.cfm>.

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## New Fellows Elected through the Forum

We are honored to report that four members of the APS were elected to Fellowship at the November Council meeting through FPS nomination. These are **Siegfried Hecker** (Stanford University), for his outstanding leadership in promoting better nuclear security and international cooperation and understanding with Russia, South Asia, and North Korea, in preventing nuclear terrorism, and in ensuring a safe, secure, and reliable U.S. nuclear arsenal, **Raymond Jeanloz** (UC-Berkeley) for his contributions to the development of sound public policy for nuclear weapons management and nuclear non-proliferation and for engaging scientists in Russia, China, and India in order to address technical and potentially sensitive issues in international security, arms control and disarmament, **Usha Varshney** (National Science Foundation) for her outstanding leadership and advocacy in advancing and promoting the fundamentals of device physics by formulating innovative and visionary research and education programs in spin and flexible electronics, and **Richard Wolfson** (Middlebury College) for his outstanding work in general physics education, in contributing to the local and state communities in Vermont in striving to achieve carbon neutrality, and in research in astrophysics involving numerous undergraduates.

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## Call for APS Fellowship Nominations

The APS Fellowship program for 2010 is open for nominations. Forum members are invited to submit nominations for consideration by the Forum’s fellowship committee. Nominations are to be made through the APS’s online system; the deadline is July 1, 2010. Information on APS fellowship may be found at <http://www.aps.org/programs/honors/fellowships/nominations.cfm>.

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## AIP Congressional Fellowships Deadline

The deadline for applications for the AIP Congressional Fellowship Program is January 15, 2010. Congressional Fellowships are an opportunity for physicists who want to apply their knowledge and skills beyond the lab bench to the conduct of national policy. After a two-week orientation in Washington, Fellows work with congressional offices to select an assignment in the office of a Member of Congress or for a congressional committee. The fellowship term is for one year, usually running September through August. Benefits include a stipend of \$65,000 per year, a relocation allowance, an allowance for in-service travel for professional development and reimbursement for health insurance up to a specified maximum. Further information and application instructions can be found at <http://aip.org/gov/fellowships/cf.html>.

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## APS Council Refers Climate Change Statement to POPA

In our October edition we reported that APS President Cherry Murray had appointed an ad-hoc committee to review the Society's 2007 statement on climate change in response to a petition put forth by a member of APS Council. The committee was charged with reviewing the statement and making a recommendation as to whether or not the it should be changed and with suggesting new wording if necessary. As reported on the APS website on November 10, the committee recommended that the Council reject the petition and that the current statement be allowed to stand, but also requested that the Society's Panel on Public Affairs (POPA) examine the statement for possible improvements in clarity and tone. The text of the web release is reproduced below; the report of the Kleppner committee is accessible to APS members at <http://www.aps.org/policy/reports/climate>.

*The Council of the American Physical Society has overwhelmingly rejected a proposal to replace the Society's 2007 Statement on Climate Change with a version that raised doubts about global warming. The Council's vote came after it received a report from a committee of eminent scientists who reviewed the existing statement in response to a petition submitted by a group of APS members. The petition had requested that APS remove and replace the Society's current statement. The committee recommended that the Council reject the petition. The committee also recommended that the current APS statement be allowed to stand, but it requested that the Society's Panel on Public Affairs (POPA) examine the statement for possible improvements in clarity and tone. POPA regularly reviews all APS statements to ensure that they are relevant and up-to-date regarding new scientific findings. Appointed by APS President Cherry Murray and chaired by MIT Physicist Daniel Kleppner, the committee examined the statement during the past four months. Dr. Kleppner's committee reached its conclusion based upon a serious review of existing compilations of scientific research. APS members were also given an opportunity to advise the Council on the matter. On Nov. 8, the Council voted, accepting the committee's recommendation to reject the proposed statement and refer the original statement to POPA for review.*

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### *Editorial Comments, continued from page 1*

production of this isotope using low enriched uranium (LEU). H.R. 3276 is now pending before the Senate Committee on Energy and Natural Resources.

Our feature articles this month continue our coverage of nuclear, global warming, and energy issues. Steven Bielski writes on the status of the CTBT monitoring system, while Pierre Goldschmidt offers comments on the future of nuclear non-proliferation, remarks he made at the APS meeting held in St. Louis in April 2008 upon receipt of the Forum's Burton Award. The history of these issues goes right back to World War II, and for some historical context along these lines we have an interesting article by Robert Potter on efforts to preserve the Hanford B reactor – the world's first plutonium production reactor – as a public museum. Former

P&S editor and longtime contributor Art Hobson writes on how lessons learned from dealing with ozone depletion in the 1980's can help in the development of policies to address global warming, and Robert Ehrlich describes his efforts at teaching renewable energy; his article includes a link to a website he has developed that offers resources in this area and that is freely available to interested users.

In this edition of P&S we begin a new column, "Opportunities." The purpose of this column is to provide a space for announcements of positions, grants, fellowships, sabbatical opportunities and the like that have a clear "physics and society" orientation. We would be happy to consider such announcements for publication.

—Cameron Reed

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## FPS-Sponsored Sessions at March and April Meetings

This year, APS has joined with the American Association of Physics Teachers to hold its traditional “April” meeting from February 13-17 in Washington, DC. The following are the sessions that APS has organized for that meeting:

*Saturday, February 13, 8:30 am*

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### **Art and Physics**

COSPONSORED WITH THE AAPT

*Teaching Science through Drawing* | **Felice Frankel, Harvard University**

*Perspective of an Artist Inspired by Physics* | **Jim Sanborn**

*Using Art to Teach Science* | **George Whitesides, Harvard University**

*Saturday, February 13, 10:45 am*

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### **Secrecy and Physics**

COSPONSORED WITH FORUM ON THE HISTORY OF PHYSICS

*Secrecy and Physicists: Intersections of Science and National Security* | **Steven Aftergood, Federation of Atomic Scientists**

*Physics and Modern Secrecy* | **Peter Galison, Harvard University**

*Secrecy in Science* | **William Happer, Princeton University**

*Saturday, February 13, 1:30 pm*

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### **Nonproliferation**

*A Plutonium Expert's Perspective on Nuclear Arms Control: Experiences in the former Soviet Union, Northeast Asia, and South Asia* | **Siegfried Hecker, Stanford University**

*Using Physics Tools to Achieve Greater Nuclear Security* | **Pavel Podvig, Stanford University**

*Sunday, February 14, 10:45 am*

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### **Physicists Inside the Beltway**

COSPONSORED WITH THE AAPT

*Perspective from Capitol Hill and the Nuclear Regulatory Commission* | **Peter Lyons, Consultant**

*Perspective from the Executive Branch* | **Brendan Plapp, US State Department**

*Perspective from Academia and Government* | **Allen Sessoms, University of the District of Columbia**

*Monday, February 15, 10:45 am*

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### **Energy Education**

COSPONSORED WITH THE FORUM ON EDUCATION

*Energy Education from the Perspective of an Energy Efficiency Expert* | **Alan Meier, University of California, Davis**

*Educating High School and Middle School Teachers and Students about Energy Systems* | **Mary Spruill, The National Energy Education Development Project**

*Energy Education for Undergraduates and the General Public* | **Richard Wolfson, Middlebury College**

*Tuesday, February 16, 10:45 am*

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### **FPS Awards Session**

*Forum Burton Award Talk* | **Pervez Hoodbhoy, Quaid-i-Azam University, Islamabad, Pakistan**

*Forum Burton Award Talk* | **Abdul Nayyar, Sustainable Development Project, Islamabad, Pakistan**

*Fissile Material Production and its Role in Proliferation and Nuclear Terrorism* | **Frank von Hippel Princeton University**

For the March 2010 APS meeting to be held in Portland, OR, FPS has organized a number of programs of interest:

*Monday, March 15, 11:15 am*

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## **How to Interest Middle School Children in Physical Science**

COSPONSORED WITH THE FORUM ON EDUCATION

*Roles for Scientists, Even in Industry, that Improve Middle and High-School Science* | **Lawrence Woolf, General Atomics**

*Introducing Deep Underground Science to Middle Schoolers: Challenges and Rewards* | **Margaret Norris, LIGO Livingston Observatory**

*Creating Engaging Science Learning Experiences for Middle School Students through Museum Exhibits* | **Ray Vandiver, Oregon Museum of Science and Industry**

*Immersing Southeastern Louisiana Middle School Students in Physics at the LIGO Livingston Science Education Center* | **Amber Stuver, LIGO Livingston Observatory**

*Teachers on the Leading Edge: A Place-Based Professional Development Program for K-12 Science Teachers* | **Robert Butler, University of Oregon**

*Tuesday, March 16, 8 am*

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## **Opportunities for Research and Employment in Transportation Science**

*The Science of Transportation Analysis and Simulation* | **John Gleibe, Portland State University**

*The Physics of Congestion Pricing in Transportation Planning* | **David M. Levinson, University of Minnesota**

*The Changing Science of Urban Transportation Planning* | **Tom Kloster, Oregon Metro Regional Transportation Planning Manager**

*Transportation Science, Planning and Employment in the Industry* | **Carl Springer, DKS Associates, Portland, Oregon**

*Wednesday, March 17, 8 am*

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## **Physics, Culture and the Arts**

*Physics and the Making of "The Big Bang" TV Comedy Series* | **David P. Saltzberg, University of California, LA**

*Dance and Movement: Collaborating with Scientists* | **Jodi Lamask, Artistic Director for Capacitor, San Francisco**

*Science and Sculpture: Physics, Mathematics and Architecture* | **Michael Burke, New York, NY**

*Understanding Musical Instruments: Composing "Updike's Science"* | **Brian W. Holmes, San Jose State University**

*Wednesday, March 17, 11:15 am*

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## **Science and Literacy, the Nature of Science and Religion**

NOT SPONSORED BY FPS BUT OF POSSIBLE INTEREST TO MEMBERS

*Culture without Science* | **Sheril Kershenbaum, Duke University**

*The Development of Civic Scientific Literacy in the US* | **Jon Miller, Michigan State University**

*Addressing the Public about Science and Religion* | **Murray Peshkin, Argonne National Laboratory**

*Increasing Our Understanding of How Science Really Works* | **Judy Scotchmoor, University of California Museum of Paleontology**

*Physics Literacy for All Students* | **Art Hobson, Univ of Arkansas**

*Thursday, March 18, 11:15 am*

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## **Renewable Energy Education**

COSPONSORED WITH THE FORUM ON EDUCATION

*NREL's Education Program in Action in the Concentrating Solar Power Program Advanced Materials Task* | **Cheryl Kennedy, National Renewable Energy Lab**

*Evolution of a New Degree Program: the BS in Renewable Energy Engineering* | **Robert Bass, Oregon Institute of Technology**

*Students and Mentors, Mentors and Students: Who is Educating Whom in the New World of Energy?* | **Daniel Kammen, University of California, Berkeley**

*Modernizing the Physics Curriculum by Being Less Modern: Case Studies from Industry* | **Philip Gleckman, eSolar**

*Renewable Energy around the Nation: Lessons Learned by One Faculty Member New to the Field* | **Robert Ehrlich, George Mason University**

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# LETTERS TO THE EDITOR

*To the Editor:*

The Tutorial of David Hafemeister & Peter Schwartz's on the Basic Physics of Climate Change in the July 2008 edition of *Physics & Society* appears compact and straightforward. However, three major flaws or omissions make one doubt the validity of the main conclusion.

(1) In the discussion of CO<sub>2</sub> content only anthropogenic fluxes are considered; the authors fail to mention that the 7.1 Gton/year are < 10% percent of the total fluxes within the biosphere. It is not until they reach the result that about 50% of the anthropogenic contribution disappears that they mention "sinks." This omission is serious. For example, the "photosynthetic sink" is net 51.5 Gton/yr (IPCC, 2007). Secondly the magnitude depends upon the CO<sub>2</sub> concentration in the atmosphere. Other natural fluxes are treated as a constant background, but in reality they are coupled and vary with temperature.

(2) The authors obtain the temperature gradient of the atmosphere as a result of radiative exchange layer-by-layer. In fact, radiation is only a part of the total energy flux through the atmosphere. Evaporation and latent heat are mentioned but never enter their calculations. In reality, these dominate the heat transport in the tropical zone, or wherever the humidity is large. The adiabatic expression gives almost the correct temperature gradient (approx 9 °C/km) by using ideal gas properties and gravity using no radiation at all. But considering only radiative transport or adiabatic pressure drop are extreme cases; both are insufficient in addition to not including latent heat.

(3) The conclusion about the insufficiency of solar variations as a cause for the global temperature increase is incomplete. The authors only discuss variation of the solar intensity at the top of the atmosphere instead of the intensity at sea level, which is strongly modulated by low clouds. Only a small increase (a few percent) in cloud cover is sufficient to explain the global temperature change. Workers at the National Space Institute of Denmark have proposed and partly demonstrated a detailed mechanism for solar influence upon the formation of clouds [1, 2].

Furthermore, it is not historically correct that Svante Arrhenius "first suggested in 1896 that..." In this work Arrhenius referenced Fourier and Tyndall for their much earlier suggestion that the climate was controlled by the amount of CO<sub>2</sub> in the atmosphere. In this 1896 article he made the first quantitative estimate of the climate sensitivity [3]. Considering that the spectral results were poorly resolved and otherwise defect, the result 3-4 °C for doubling the concentration of CO<sub>2</sub>

was amazingly close to the IPCC claims today. However, it is very rarely mentioned that Arrhenius 10 years later published a calculation resulting in a much lower effect of CO<sub>2</sub> [4].

Finally, the sentence "It is our belief that 'theory leads experiment' on climate change because all well-accepted atmospheric models predict a temperature rise" is unfortunate. If the models are based on the same incorrect assumption, their validity is not ensured by the fact that they agree. Furthermore they should at least give reference to some experiments. For instance, references 5-8 are based on measurements, and they all agree that the current climate models use climate sensitivity values that are significantly too large and thus exaggerate the importance of CO<sub>2</sub>, anthropogenic or not, in the atmosphere.

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*These contributions have not been peer-reviewed. They represent solely the view(s) of the author(s) and not necessarily the views of APS.*

1. N. D. Marsh and Henrik Svensmark "Low Cloud Properties Influenced by Cosmic Rays." *Phys. Rev. Lett.* **85**:23, 5004 (2000).
2. H. Svensmark, T. Bondo, J. Svensmark "Cosmic ray decreases affect atmospheric aerosols and clouds." *Geophys. Res. Lett.* **36**, L15101, doi:10.1029/2009GL038429, (2009).
3. S. Arrhenius "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground." *Phil. Mag. Ser. 5*, vol. 41, 237 (1896).
4. S. Arrhenius "Die Vermutliche Ursache der Klimaschwankungen." *Medd. Roy. Acad. Nobel Inst. Band 1:2*, 1 (1906)
5. R. W. Spencer et al. "Cloud and radiation budget changes associated with tropical intraseasonal oscillations." *Geophys. Res. Lett.* **34**, L15707, (2007) doi:10.1029/2007GL029698.
6. David H. Douglass et al. "A comparison of tropical temperature trends with model predictions." *Int. J. Climatol.* **28**,1693-1701, (2008)
7. R. S. Lindzen et al. "On the determination of climate feedbacks from ERBE data." *Geophys. Res. Lett.* **36**, L16705, (2009) doi:10.1029/2009GL03962
8. G. Paltridge et al. "Trends in middle- and upper-level tropospheric humidity from NCEP reanalysis data." *Theor. Appl. Climatol.* DOI 10.1007/s00704-009-0117 (2009).

*Hafemeister & Schwartz respond:*

We thank Professor Ribbing for his interest in our work. Our responses to the points he raised follow:

1. The large natural fluxes of CO<sub>2</sub> are approximately balanced. The increase in CO<sub>2</sub> emissions from humans raises the CO<sub>2</sub> atmospheric concentration, which raises radiative forcing and surface temperature.

2. Our three-page paper, "Tutorial on the Basic Physics of Climate Change," closely follows Chapter 8 in Hafemeister's text, *Physics of Societal Issues* (Springer, 2007). Because of

the need to be brief, we did not quantify the more difficult convective (lapse rate) and latent heat (evaporation) transport, but these are estimated in the text at pages 210-211. Kevin Trenberth's article in the April 2009 issue of P&S has a more lengthy discussion of this and he gives energy flow rates of 17 W/m<sup>2</sup> for convection, 80 W/m<sup>2</sup> for evapo-transpiration and a net infrared flow of 63 W/m<sup>2</sup> [1]. An excellent discussion of the convective contribution is given by Thomas Ackerman [2]. His Figure 6 shows the radiative-equilibrium and the radiative-convective-equilibrium temperatures to be similar at 15 km altitude, but with substantial differences at lower altitudes. Ultimately the best answers are obtained from General Circulation Model cellular calculations since closed form equations with no cellular structure are not sufficient.

3. Solar variations. The 2007 Intergovernmental Panel on Climate Change concluded that the anthropogenic radiative forcing in 2005 from CO<sub>2</sub> was 1.66 W/m<sup>2</sup> (1.49 to 1.83), plus another 1.35 W/m<sup>2</sup> from five other greenhouse gasses. At this time aerosols make a negative contribution of -1.2 W/m<sup>2</sup>, but this is not expected to grow substantially, whereas the density of greenhouse gases is increasing. These contributions are much larger than the increased irradiance from solar-cycle variations and fluctuations of 0.12 W/m<sup>2</sup> (0.06 to 0.30). The IPCC stated that the level of understanding of CO<sub>2</sub> forcing was "high," as compared to a "low" level of understanding for variations in solar cycle forcing [3]. For one thing, it's hard to explain the increased solar warming over the past thirty years when there hasn't been an upward trend in solar intensity over the same time period [4]. That is not to say that researchers don't look at the impact of the sun. For example, the recent paper by Gerald Meehl, et al uses global climate models to explore how relatively small fluctuations of the 11-year solar cycle can produce the magnitude of the observed climate signal in the tropical Pacific associated with such capability [5]. They note, however, that "This response cannot be used to explain recent global warming because the 11-year solar cycle has not shown a measurable trend over the past 30 years."

4. Svante Arrhenius was the first to develop an energy budget model to quantify the rise in ground temperature [6]. He obtained a rise of 3 to 3.5 °C from a doubling of CO<sub>2</sub>. In general terms he stated that "if the quantity of carbonic acid increases in geometric progression, the augmentation of the temperature will increase nearly in arithmetic progression." Today, the Arrhenius greenhouse law for direct warming from CO<sub>2</sub> (only) is written as  $\Delta F = \alpha \ln(C/C_0)$ , where F is radiative forcing,  $\alpha$  is 3.75 W/m<sup>2</sup>, C is atmospheric CO<sub>2</sub> concentration, and C<sub>0</sub> is the pre-industrial level of 280 ppm.

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- [1] K. Trenberth, "Changes in the Flow on Energy through the Earth's Climate System," *Physics and Society* 38(2), 11-16 (April 2009) and "An Imperative for Climate Change Planning: Tracking Earth's Global Energy," *Current Opinion in Environmental Sustainability* 1, 19-27 (2009).
- [2] T. Ackerman, "A Tutorial on Global Atmospheric Energetics and the Greenhouse Effect," *Global Warming: Physics and Facts, AIP Conference Proceedings* 247 (1991), ed. by B.G. Levi, D. Hafemeister and R. Scribner.
- [3] Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Basis (IPCC, Geneva)*, pp. 1.4.
- [4] P. Duffy, B. Santer and T. Wigley, "Solar Variability Does Not Explain late-20<sup>th</sup>-Century Warming," *Physics Today* 62, 48-49 (January 2009).
- [5] G. Meehl, J. Arblaster, K. Matthes, F. Sassi and H. van Loon, "Amplifying the Pacific Climate System Response to a Small 11-year Solar Cycle Forcing," *Science* 325, 1114-1118 (2009).
- [6] S. Arrhenius, "On the Influence of Carbonic Acid upon Temperature of the Ground," *Philosophical Magazine* 41, 237-276 (1896).

*To the Editor:*

The article on the medical isotope shortage [Physics & Society 38(4), 13-16, October 2009] covered the topic quite well, except for one very important production alternative that the author does not mention. It is feasible to produce very large quantities of Mo-99 in any CANDU power reactor because of its on-power refueling capability. The thermal neutron flux in a CANDU is about 50% greater than in a MAPLE reactor, and the standard 37-element fuel bundle could be modified to accommodate a number of MAPLE "target" elements. The refueling machines could be employed to load several "target" bundles into just one of the (several hundred) fuel channels and remove them after one week of irradiation.

This option has been known for a long time, but has not been pursued because it is inconvenient for the CANDU operator. However, the very important significance of the Mo-99 shortage is leading to a reassessment of this alternative.

An Expression of Interest (EOI) to produce Mo-99 by this method has been submitted to the Isotope Expert Review Panel, established by Natural Resources Canada this past summer. This panel is reviewing the 22 different EOIs that were received; it will make recommendations in November.

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*These contributions have not been peer-refereed. They represent solely*  
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*To the Editor:*

Elizabeth Dowdeswell's article in the October 2009 edition of Physics & Society describes the Canadian campaign to create social acceptance of nuclear waste and identify a community that will host a repository [1]. Left unstated in her

article is that part of the reason for the necessity of this extensive effort is the perception, shared by many in the scientific community, that any ionizing radiation exposure caused by human activity can cause cancer deaths [2]. This perception is a barrier to on-going and increased use of nuclear energy. The linking of nuclear technologies to an increased risk of cancer mortality (and congenital malformations) is traceable to the linear no-threshold (LNT) assumption of radiation carcinogenesis. This assumption holds that cancer mortality increases linearly with exposure, with no minimum threshold for causing cancer deaths. A 2001 article in P&S questions the validity of the LNT concept [3].

The Health Physics Society and the American Nuclear Society have both issued position statements that there is no statistically significant evidence that a low radiation dose causes cancer [4, 5]. Indeed, there is evidence that low doses produce beneficial health effects in all living organisms, and a model of this phenomenon has been formulated [6]. However, regulatory authorities ignore this information, and risk analysts continue to calculate the number of fatal cancers that will be caused by a very small "population exposure." Lauriston Taylor, former president of the National Council on Radiation Protection and Measurement, denounced the calculation of the number of deaths per year resulting from x-ray diagnoses: "These are deeply immoral uses of our scientific heritage." "No one has been identifiably injured by radiation while working within the first numerical standards set by the International Commission on Radiological Protection (ICRP) in 1934 (safe dose limit: 0.2 rad per day)" [7, 8].

Another issue is that society has accepted the notion that used nuclear fuel is "waste," but this material really represents an enormous energy resource for future generations. Compared with fossil fuel combustion products, the amount of used nuclear fuel is very small and it is being stored in very heavy, robust containers made of steel and reinforced concrete. No one is being injured by used fuel and there is no reason to believe that anyone will be injured by it in the foreseeable future.

For nuclear energy to play a significant role in meeting future needs, it is essential that the regulators reexamine the scientific evidence and communicate the real health effects. Negative images and implications of health risks derived by unscientific extrapolations of harmful effects of high doses must be dispelled. Furthermore, scientists need to explain to society the nature of (slightly) used nuclear fuel, pointing out the enormous energy potential of the unfissioned uranium and transuranic materials and identifying the real waste, i.e., the fission products, which are not difficult to manage.

- [1] Dowdeswell, E. "A Contract Between Science and Society: The Canadian Experience with Nuclear Waste Management," *Physics and Society* 38(4), 17-19 (2009).
- [2] Brenner, DJ and Hall, EJ. "Computed Tomography – An Increasing Source of Radiation Exposure," *N Engl J Med* 357, 2277-2284 (2007).
- [3] Cameron, J. "Is Radiation an Essential Trace Energy?" *Physics & Society* 30(4), 14-16 (2001). Available at: <http://www.aps.org/units/fps/newsletters/2001/october/index.html>. See also <http://apsweb.aps.org/publications/apsnews/200403/backpage.cfm>
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*These contributions have not been peer-refereed. They represent solely the view(s) of the author(s) and not necessarily the views of APS.*



# ARTICLES

## Panel Discussion on the International Monitoring System of the Comprehensive Test-Ban Treaty: The North Korean Test of October 2006 and Future Prospects

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*Transcribed from video by Drew Masada and Sarah Williams, The University of Texas at Austin*

### Introduction

Nuclear explosion monitoring is a timely topic due to clandestine nuclear activities recently observed in Iran and the Democratic Peoples Republic of Korea (DPRK; North Korea). Recent discoveries reveal a covert uranium enrichment facility in Iran that may indicate activities leading towards the development of nuclear weapons. DPRK has two recent nuclear weapons tests: one on October 9, 2006 and the other on May 25, 2009.

The Comprehensive Nuclear Test Ban Treaty (CTBT) was adopted by the United Nations General Assembly on September 10, 1996. The CTBT bans all nuclear explosions in all environments. The treaty has not yet entered into force, but the Provisional Technical Secretariat (PTS) has been established in Vienna, Austria. [Editor's note: The US Senate rejected ratification of the treaty in October, 1999. The US and eight other countries that possess nuclear power or research reactors must ratify the treaty before it enters into force.] Within the PTS an International Monitoring System (IMS) has been developed, as defined in the treaty, to monitor the world for nuclear explosions. The IMS contains sensors for four monitoring technologies: radionuclide (80 stations and 16 laboratories), seismic (50 primary and 120 auxiliary stations), hydroacoustic (11 hydrophone stations), and infrasound (60 surface stations). The network of IMS stations was configured to obtain a near-uniform monitoring capability around the world. Once the treaty goes into force, CTBT Member States may request an on-site-inspection (OSI) to be carried out if data from the IMS stations indicates that a nuclear explosion has occurred. On-site-inspection is limited to an area of 1,000 square kilometers in regions controlled by CTBT participating nations. This article focuses on the radionuclide

monitoring component of the IMS.

On April 10, 2009, a panel discussion on CTBT monitoring was held during the 8<sup>th</sup> International Conference on Methods and Applications of Radiochemistry (MARC VIII) to discuss the data from the DPRK event and the general radionuclide monitoring capability of the IMS. This article summarizes the panel discussion. The second North Korean nuclear explosion took place after the panel discussion occurred.

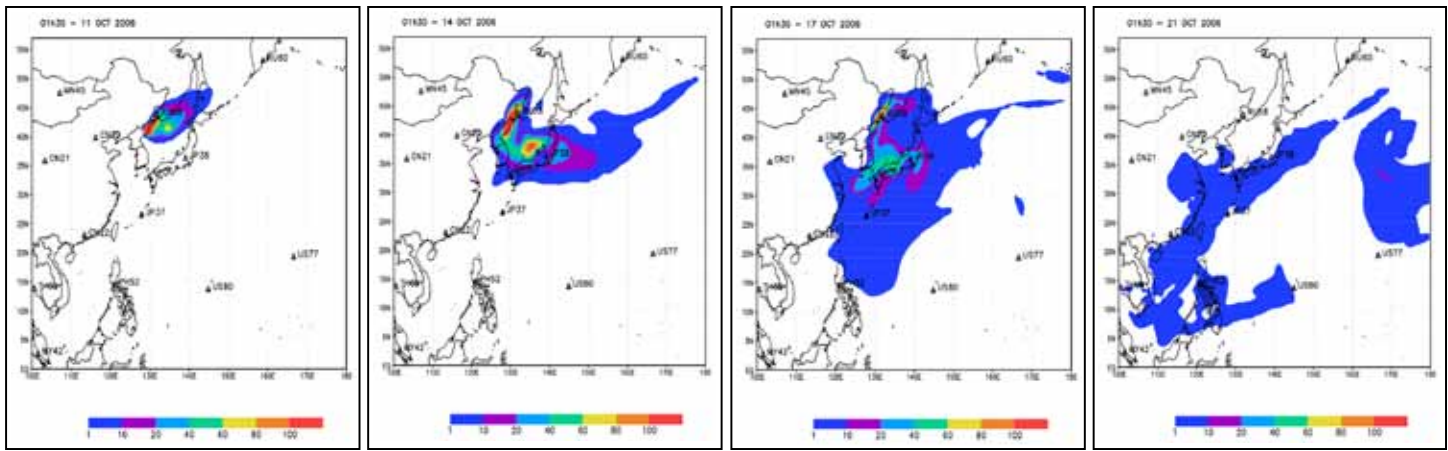
The panel was moderated by the author. The six panel members were, in alphabetical order, 1) Dr. Guy Brachet of the Commissariat à l'Énergie Atomique (CEA) in France, 2) Mr. Fitz Carty, Senior Program Manager at General Dynamics Advanced Information Systems, USA, 3) Dr. Harry Miley from Pacific Northwest National Laboratory, USA, 4) Dr. Anders Ringbom from the Swedish Defense Research Agency, Sweden, 5) Dr. Robert Werzi of the PTS of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Austria, and 6) Dr. Matthias Zähringer of the PTS of the CTBTO, Austria.

### The 2006 DPRK Test

Figure 1 shows part of the planned worldwide IMS network of radioisotope detectors. The complete IMS includes 80 air-monitoring radionuclide detection stations, 40 of which will have noble-gas detection capability. Sixteen radionuclide



Figure 1. Test Site and IMS Stations



Average Volume Activity 10 Oct – 11 Oct    Average Volume Activity 13 Oct – 14 Oct    Average Volume Activity 16 Oct – 17 Oct    Average Volume Activity 20 Oct – 21 Oct

Figure 2. Atmospheric transport of radioxenon following DPRK event utilizing the Lagrangian model FLEXPART with NCEP FNL  $1^\circ \times 1^\circ$  metrological data (units of  $\text{mBq m}^{-3}$ ).

laboratories support the detection network. Data from the IMS is sent to the International Data Center (IDC) in Vienna, where it is processed, analyzed, and disseminated to member states. (Data is available for scientific use upon request.) Radioxenon from the North Korean test was detected at the Yellowknife, Canada, station (CA16 in Figure 1) with a peak  $^{133}\text{Xe}$  concentration of  $0.74 \pm 0.06 \text{ mBq m}^{-3}$  [1 Bq = 1 decay/sec;  $^{133}\text{Xe}$  has a beta-decay half-life of about 5.2 days]. While this is a low environmental quantity of radioxenon, it is significantly above the detection capability ( $\sim 0.3 \text{ mBq m}^{-3}$  for  $^{133}\text{Xe}$ ) of radioxenon monitoring systems developed for CTBT monitoring. All panel members concurred with the opinion that the planned full IMS network would have measured the DPRK event more accurately than the partial network that was operational at the time (only eleven noble gas stations were operating at the time of the event), and placed a high priority upon completion of the network.

Rather than one station detecting the event, the planned network would have had two or three stations capable of detecting radioxenon in the range of  $10\text{-}100 \text{ mBq m}^{-3}$  of  $^{133}\text{Xe}$ . More stations able to record significant amounts of activity in the atmosphere following a nuclear event allows for better atmospheric backtracking and definition of a possible source region and hence increases the likelihood that the event will be correctly identified and located. Data gathered by the Yellowknife station after the DPRK event was used to predict the capabilities of the planned network to detect significant amounts of xenon in the atmosphere. The images shown in Figure 2 are the modeled average activity concentration of radioxenon around the North Korean test site 12 days after the event.

The four stations listed below, if operational, would have detected the indicated corresponding amounts of  $^{133}\text{Xe}$ , all of

which are significantly higher than the  $1 \text{ mBq m}^{-3}$  detection limit defined by the CTBT for IMS noble gas stations for this isotope. Actual noble gas systems have significantly better  $^{133}\text{Xe}$  detection limits that can range down to values as low as  $0.3 \text{ mBq m}^{-3}$  or even lower.

- RU58 (maximum calculated activity  $\sim 80 \text{ mBq m}^{-3}$ )
- JP38 (maximum calculated activity  $\sim 12 \text{ mBq m}^{-3}$ )
- JP37 (maximum calculated activity  $\sim 7 \text{ mBq m}^{-3}$ )
- PH52 (maximum calculated activity  $\sim 5 \text{ mBq m}^{-3}$ )

Other stations in Fig. 1 were not sensitive to this test because of dominant wind patterns in the area at the time following the explosion. Stations in the US and Mexico are too far from the test site to detect the event. While a fully-operational IMS network would have had two or three stations detect atmospheric radioxenon following the DPRK event, increased sensitivity at existing stations might also have allowed the detection of radioiodine.

## Radionuclide Background

The nature of radionuclide backgrounds is controversial. Some panel members emphasized that backgrounds are complex and site-specific with average concentrations varying over several orders of magnitude. This may require site-specific criteria to separate normal background from treaty-relevant detections. Others suggested that backgrounds are mostly composed of  $^{133}\text{Xe}$ , normally distributed over stations, and maintain some consistency across station sites. Occasionally  $^{131\text{m}}\text{Xe}$  (half-life 11.9 days) is present. These two xenon signatures would compose the majority of the backgrounds. The panelists believed that the state of technol-

ogy and equipment has improved, allowing them to measure radioxenon concentrations not previously detectable.

The second issue regarding radionuclide backgrounds is identifying and cataloging known sources of radionuclide production that are part of the world-wide background. Excluding nuclear tests, there are two main sources of radioxenon isotopes in the environment: radionuclide production facilities and nuclear power plants. Monitoring stations in close proximity to emitting sources will pick up  $^{133}\text{Xe}$  and  $^{135}\text{Xe}$ . The panelists believed that future research should gather data on what these civil sources produce, in what quantities, and their emissions on a daily basis.

Finally, experts place a high priority upon completing the network as soon as reasonably achievable. A completed network will have superior detection capabilities. The CTBTO has fourteen stations planned to be installed in the next few years that will expand the network and draw near to the 40 noble gas system network.

Further investment aiming at having a noble gas detector at each of the 80 radionuclide stations would further enhance the detection capability of the network. A few stations may be difficult to install due to political reasons such as non-signature of potential host countries. Efforts should be directed at avoiding gaps that degrade the homogeneous performance of the network.

## Future Development of the International Monitoring System

While the current IMS radionuclide monitoring system meets CTBT requirements, it is expected that technology will improve. These advancements should be integrated into the IMS monitoring system to increase performance and reliability. A process for approving new system components for the network and the factors that might facilitate or hinder the process must be considered. Assuming that the CTBTO would update the network either by upgrading the pre-existing system or installing new detectors, it could be ten or more years from the time the details are worked out to the point where a new detection system is deployed.

Issues in examining radionuclide backgrounds include factoring in new discoveries, cataloging known sources of radionuclides, and completing the network. It is expected that radionuclide backgrounds will change due to the addition of new radiopharmaceutical production facilities and new commercial nuclear reactors. Since this background is not constant, it must be continually monitored, analyzed, and documented.

Detection techniques for OSI have yet to be fully developed. There are many scientists in the field who are waiting

for the opportunity to contribute to OSI, and have developed related projects. Improved monitoring and detection capabilities for OSI teams are gaining support and funding from the policymaking community. The decision to rely on one type of monitoring originated with a cost-benefit analysis going back to the conception of the CTBT detection network. This situation fostered an environment in which radiochemistry is not the priority detection method of the network. The panel is not aware of better analytical techniques given the operational considerations and necessary detection limits. However, should such technology become available, steps should be taken to incorporate the technology as appropriate.

In addition, improvements to the Atmospheric Transport Model (ATM) software have created better tracking and modeling of potential sources. This is another issue relevant to obtaining a broad acceptance of calibration techniques for noble gas systems and would help to improve the reliability of the data. Most of all, the IMS needs to continue to collect data. The more data that is collected, the more it helps to prove the capability of the system. In Vienna, the CTBTO is leading efforts to organize the International Scientific Symposium (ISS 2009). The goal of the symposium is to assess the current capability and future potential of the verification regime.

To address concerns about the perceived lack of alternatives or new technology being incorporated into the IMS, it should be noted that available new cooling technologies for HPGe detectors are not capable of withstanding the technical and environmental pressures of the current IMS network. (Detector cooling to  $\sim 70$  K is necessary to reduce electronic noise in the detector.) Network engineers rely on what is currently on the market, however, lab-tested systems are not necessarily robust enough for field deployment. New developments have also increased the availability of ultra-low background HPGe detectors. This technology could potentially lead to significant detection limit improvements for the measurements of aerosol samples at IMS stations and laboratories. Consequently, the feasibility of measuring radioiodine releases from underground nuclear tests could be improved. This panel highly recommends that funding be made available for testing new technology, research, and development for feasibility of field deployment as well as improvements to detection limits.

## Conclusion

Over the past decade, the IMS has progressed significantly, steadily increasing the number of certified stations worldwide. The CTBTO and its related scientific community continue to look for opportunities to improve detection techniques and means to improve the technical capacity of the network. The efforts of the CTBTO and others in the field

have helped to bring the CTBT verification regime closer to becoming fully operational. Specifically, past efforts by the scientific community have led to better understanding of the radionuclide background and to overcome deficiencies in the IMS. On the issue of radionuclide background, scientists now have evidence that radionuclide production facilities are the major sources that contribute to these background levels. They know the location of most facilities and what they produce. What is now needed are the exact quantities of daily emissions from these facilities.

Regarding deficiencies in the IMS network, there has been progress towards becoming fully operational. High quality data is available and system reliability is significantly improved over the last seven years. System detection limits may now be calculated with *post priori* data to better assess IMS capabilities.

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*These contributions have not been peer-reviewed. They represent solely the view(s) of the author(s) and not necessarily the views of APS.*

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## Nuclear Non-Proliferation: The Future Depends On Us

*Pierre Goldschmidt*

*The following article is adapted from Dr. Goldschmidt's remarks made upon receipt of the Forum's Burton award at the APS meeting held in St. Louis, MO, April 2008. We apologize for the serious delay in getting Dr. Goldschmidt's remarks into print – Ed.*

### Introduction: Nuclear Safety & Geo-Politics

I am greatly honored and most grateful to have been selected to receive the 2008 Joseph A. Burton Award. I have been very fortunate to have been the Head of the Agency's Department of Safeguards at a time when the Department had to respond to a number of major proliferation challenges.

There are presently clear indications that we are about to see a revival of nuclear energy worldwide. It is important to make this expansion of nuclear energy for the production of electricity and desalinated water as safe and secure as possible. This expansion will however, in the coming decade, be limited by a number of socio-economic factors as well as industrial limitations such as the capacity to manufacture reactor vessels. This should give us time to "do" nuclear right, not under an unwarranted rush. Doing it right means, in particular, putting stronger barriers to proliferation in place before, not after, new nuclear capabilities spread. What is of concern is that some states that have recently indicated interest in acquiring nuclear power plants (NPP) seem to be motivated by geo-political considerations as much as by economic or environmental factors. It is also worrisome to see some supplier states racing to offer their services to countries where starting an electro-nuclear program now does not necessarily appear to be the best or a priority option. Organizations such as the IAEA can help in laying out objective, well studied criteria to judge when and where nuclear energy makes sense and where it does not.

In the short term, in order to compensate for the lack of adequate industrial infrastructure and nuclear safety culture in some recipient states, suppliers may offer so-called "BOT contracts," whereby they would build, operate and later transfer the NPP to the buyer. That might work initially in

few cases, but the question is whether it is sustainable in the longer term. Are we really going to see Russian, French, American or Chinese experts being requested to assume the responsibility of operating NPPs in Libya, Jordan, the UAE and many other States? One must always keep in mind that a severe nuclear accident anywhere in the world will have damaging consequences for the whole industry, even in those countries where NPPs are operated in the safest way. Today I will not dwell on these important safety aspects; rather, I will focus on some of the non-proliferation challenges inevitably associated with a worldwide expansion of the peaceful use of nuclear energy. In order to minimize proliferation risks, it has become apparent that we must both discourage the spread of sensitive fuel cycle activities and strengthen the IAEA verification authority, in particular when a State has been found to be in non-compliance with its safeguards agreement.

### Discouraging the Spread of Sensitive Fuel Cycle Facilities

There is very little economic incentive for a non-nuclear weapon State (NNWS) to construct new fuel cycle facilities such as uranium conversion, enrichment or reprocessing plants domestically, because without the support of external sources these plants cannot be economically competitive. To further minimize any incentive to build such plants domestically, it is necessary to provide nuclear fuel supply guarantees. Even if the nuclear fuel cycle industry is an oligopoly, it should be recalled that there is not a single example in history where a State that had a Comprehensive Safeguards Agreement (CSA) in force had to close down an electrical NPP because it was denied the delivery of fresh fuel assemblies. The concern expressed by a very small number of non-aligned countries

is that the delivery of fuel assemblies to NPPs could be suspended or denied by a supplier for purely political reasons. Although the likelihood that all suppliers would deny such fuel supplies is small, this concern must be addressed seriously and rapidly.

It has been suggested that a solution would be to construct and operate multinational facilities, in particular enrichment plants, where the customers would also be shareholders, but without access to the technology. Notwithstanding the merits of such a concept, it does not address the real perceived risk which is that the exporting state will ultimately fail or refuse to grant the necessary export license in a timely manner. The ultimate guarantee against such an occurrence is for the IAEA to own a fuel reserve that would be used to provide fuel assemblies to any country that would be denied fuel delivery for purely political reasons. It is essential that such an IAEA fuel bank be established in the near future. Such a fuel reserve, to be effective, should be operated under three conditions:

(1) An IAEA low-enriched uranium fuel bank should, for practical and economic reasons, be physically located (in the form of UF<sub>6</sub>) at some, if not all commercial enrichment plant sites.

(2) The Agency should conclude contracts with all manufacturers of fuel assemblies to assure the Agency's access, in case of necessity, to some fabrication capacity.

(3) Countries where the fuel bank and fabrication plants are located should grant the IAEA a generic (or a priori) export license, subject to the IAEA confirming that a number of objective and well defined safety, security and non-proliferation conditions have been met by the recipient state, and that the recipient state does not possess domestic sensitive fuel cycle facilities.

Independently, suppliers of NPPs should also consider the merit of leasing fresh fuel assemblies required for the lifetime operation of the plants and of taking back the spent fuel, as an incentive (if not a condition) for the recipient State not to set up domestic enrichment and reprocessing activities. Spent fuel could be taken back in exchange for an equivalent quantity of well conditioned high level vitrified wastes.

## Expanding the IAEA Verification Authority

The IAEA safeguards system is being implemented more effectively and efficiently than ever before. Traditionally, the IAEA focused on accounting for nuclear materials in a state facility-by-facility. This work was done only at declared facilities and was largely an audit. Since 1998, however, the IAEA has developed a global analytical approach that asks not simply whether the declared numbers add up, but also, "*What's going on in this state's nuclear program? Is everything really consistent?*"

At the heart of this approach is the production and periodic update of State Evaluation Reports (SERs) and of a corresponding action plan. SERs combine the results of inspections in the field and environmental swipes with analysis of all relevant information from open sources, including satellite imagery. State Evaluation Reports analyze the history of all anomalies and inconsistencies recorded during previous inspections. They examine whether a state's research and development program is internally consistent, corresponds with stated purposes, and point to a commitment to use nuclear technology exclusively for peaceful uses. The SERs analyze export and import notifications regarding relevant nuclear material and equipment and other information available to the IAEA. Every SER also includes a section that examines the most likely diversion scenarios on the assumption that the state under review intends to divert nuclear material for military purposes.

Not only have the SERs become more robust, but the findings and conclusions reported by the Agency's Secretariat in its annual "Safeguards Implementation Report" have become more pragmatically informative. Starting with the "Safeguards Statement for 2003," the Secretariat's findings and conclusions were directed to five distinct categories of countries: those with a Comprehensive Safeguards Agreement (CSA) and Additional Protocol (AP) in force, those with a CSA but no AP in force, those with what is known as "66-type" safeguards agreements, those which are party to the NPT but have not yet brought a CSA into force, and the five Nuclear Weapons States (NWS). Also in 2003, for the first time, in the interest of transparency, the Agency's Board of Governors (BoG) approved the release of a 12-page "Background to the Safeguards Statement and Executive Summary." This document named 16 NNWs with known significant nuclear activities that had yet to sign and bring an Additional Protocol into force even though the Model Additional Protocol had been approved by the BoG more than six years before [As of the time of this talk, seven of these states have signed an AP but only one, Kazakhstan, has brought it into force.] It also pointed out that in the 70 States with "small quantities protocols" the Agency had only very limited means to evaluate any potential nuclear activities. [Editor's note: Safeguards are activities by which the IAEA can verify that a State is living up to its international commitments not to use nuclear programmes for nuclear-weapons purposes. An AP grants the IAEA complementary inspection authority to that provided in underlying safeguards agreements. 66-type agreements provide for the application of safeguards to specific facilities; see <<[http://www.iaea.org/Publications/Factsheets/English/sg\\_overview.html](http://www.iaea.org/Publications/Factsheets/English/sg_overview.html)>>].

Parallel with these developments, the IAEA has replaced almost all analogue video cameras with digital surveillance

cameras, and the implementation of remote monitoring has continuously increased since 2000. Progress is also being made in using more advanced equipment such as ground penetration radar to improve the IAEA's ability to verify that highly complex nuclear facilities conform to their official design. The Agency has also established a new R&D project to explore, with the support of Member States, the potential use of advanced technologies in detecting undeclared nuclear material and activities at a distance. In addition, in response to the discovery in 2004 of an extensive covert supply network of sensitive nuclear technology which came to light as a result of Libya's disclosure of its clandestine nuclear weapons program, the Agency's Department of Safeguards has established a new unit focused on documenting, investigating and analyzing nuclear trade activities worldwide, with the aim of uncovering the existence of undeclared nuclear activities.

This more rigorous, transparent and resourceful approach to safeguards has led one knowledgeable commentator (Richard Hooper – IAEA Bulletin – June 2003) to assert that *“changes in structure and practices of the Safeguards Department have been accompanied by a change in culture that is more of a revolution than evolution.”* This *“radical departure from the past practice”* has also been acknowledged in the US Government Accountability Office Report of October 2005 on Nuclear Non-proliferation. To be sure, there are still problems inherent in ensuring that in “bulk facilities” even small amounts of nuclear material (a few kilograms among tons) are not diverted without timely warning, even if the safeguards approaches for fuel cycle facilities have been improved during the last 5 years. I believe that the IAEA is in a position to provide adequate assurances that there is no diversion of nuclear material from NPPs and no undeclared nuclear material and activities in any country that does not have sensitive nuclear fuel cycle facilities and has a CSA and an AP in force with the Agency.

In contrast, the Agency's ability to provide the necessary assurances in a country that operates sensitive nuclear fuel cycle facilities and has not ratified the AP is limited. It is even lower if such a country has been found to be in breach of its obligation to comply with its safeguards agreement, or is uncooperative in resolving any question or inconsistency, or refuses or delays access to locations (e.g. to take environmental swipes) requested by the Agency or rejects or delays the installation of surveillance and containment devices equipped with remote monitoring. The non-proliferation regime needs to be strengthened.

## **Safeguards in Perpetuity**

One of the greatest weaknesses of the model Comprehensive Safeguards Agreement is its Article 26, which provides

that the Agreement is to “remain in force as long as the State is party to the Treaty on the Non-Proliferation of Nuclear Weapons”. Nothing is said about what happens if and when the State withdraws from the Treaty. It would be logical to forbid withdrawing countries the free use of material and equipment delivered to them while and because they were a Party to the NPT. Consequently, it is very important to guarantee that such material and equipment remain under IAEA safeguards even if a state withdraws from the NPT or otherwise unilaterally terminates any safeguards agreement.

It should become a norm that at least all sensitive nuclear fuel cycle facilities, even in states with a CSA, be covered also by a 66-type safeguards agreement that would specify that *“safeguards shall continue to apply with respect to nuclear material and facilities which are subject to safeguards on the date of termination of a CSA and any nuclear material produced, processed or used in or in connection with such nuclear material or facility after the termination of the CSA, including subsequent generations of produced nuclear material.”* Such an agreement would only become operative in case the state withdraws from the NPT. The Nuclear Suppliers Group (NSG) should adopt this requirement as an export condition for any material or equipment related to sensitive nuclear fuel cycle facilities. The Governments of the Netherlands, Germany and Japan should lead by example, and conclude with the IAEA such safeguards agreements for their enrichment and reprocessing facilities.

## **Non-compliance and Enforcement**

Experience has demonstrated that when a state is found to have deliberately been in non-compliance with its safeguards agreements or in breach of its obligation to comply with its safeguards agreements and does not show full transparency and cooperation for resolving questions with regard to its past or present nuclear program, the Agency will temporarily need expanded verification rights. This expanded authority, which will be in addition to that granted to the Agency under a CSA and the Model Additional Protocol will be necessary, in these circumstances, to provide in a timely manner an adequate level of assurance that there are no undeclared nuclear material and activities in that state and that no previously undeclared nuclear or other activities (e.g., weaponization or missile developments) have been undertaken to support a nuclear weapons program. This is clearly reflected in the IAEA's report of September 2005 regarding Iran to the Board of Governors, where it is stated: *“In view of the fact that the Agency is not yet in a position to clarify some important outstanding issues after two and a half years of intensive inspections and investigation, Iran's full transparency is indispensable and overdue. Given Iran's past concealment efforts*

*over many years, such transparency measures should extend beyond the formal requirements of the Safeguards Agreement and Additional Protocol and include access to individuals, documentation related to procurement, dual use equipment, certain military owned workshops and research and development locations. Without such transparency measures, the Agency's ability to reconstruct, in particular, the chronology of enrichment research and development, which is essential for the Agency to verify the correctness and completeness of the statements made by Iran, will be restricted".* The problem is that these additional transparency measures have not been defined in any precise way and that even when they are requested under an IAEA Board resolution (as was the case for Iran on 4 February 2006) they are not legally binding for the non-compliant State.

In this regard the United Nations Security Council (UNSC) should consider the merit of adopting a generic resolution, stating that if a state is found by the IAEA to be in non-compliance with its comprehensive safeguards agreement, the UNSC would, upon request by the Agency, automatically adopt a specific resolution under Chapter VII of the UN Charter requiring that state to temporarily suspend all sensitive nuclear fuel cycle-related activities and to grant to the Agency extended access rights. These rights would be used to resolve outstanding issues, and would be terminated as soon as the Agency has been able to draw the conclusion that there are no undeclared nuclear material and activities in the State and that its declarations to the IAEA are correct and complete. This mechanism would allow the IAEA safeguards system to provide the international community with more credible assurances regarding the exclusively peaceful nature of all nuclear related activities in the state in a faster, more effective and more efficient manner. These broader access rights must not exclude military sites, since it would be likely for the military to be involved in nuclear activities associated with a weapons programme, should one exist. It is clear that military sites may contain sensitive information that would not be relevant to the Agency's investigation. It is expected that Agency activities on such sites will need to be conducted under "managed access" conditions that protect such information while allowing the Agency to reach its objective. Denial of or unwarranted delays in access should be reported by the Director General to the Board of Governors and, as appropriate, to the UNSC.

As experience with North Korea and Iran taught us, one of the greatest difficulties in deterring states from violating their non-proliferation undertakings or from ignoring legally binding UNSC resolutions is their hope that for geostrategic or economic reasons at least one of the five veto-wielding members of the UNSC will oppose the adoption of harsh

sanctions. It should be easier to find consensus on a generic non-state specific resolution as the one suggested above which would have no retroactive effect. If a state has deliberately violated its NPT or safeguards undertakings and thereafter refuses to temporarily suspend sensitive nuclear fuel cycle activities as mandated by the UNSC, it should be made clear that this represents a threat to international peace and security. It would therefore seem logical for the Security Council to agree a priori that in these circumstances all military cooperation with that State would be suspended. This would constitute a strong disincentive for that State to defy legally binding UNSC resolutions, but would not impact on the well-being of its population.

## **Undeclared Nuclear Trade Activities**

As reported in August 2006 by the IAEA Secretariat, *"before 1991, the prevailing view... was that a State's nuclear activities prior to entry in force of its comprehensive safeguards agreement were not relevant to the Agency's work. This changed with Board endorsement of the Agency's right and obligation to verify not only the non-diversion of declared nuclear material, but also the absence of undeclared material and activities"*.

As far back as May 1992 the IAEA Secretariat had recommended that the Board call on all states to report to the Agency, on a quarterly basis, all exports and imports of equipment and non-nuclear material listed in an Attachment which corresponds to what is today Annex II of the AP; unfortunately, this universal reporting system was not endorsed by the Board when the recommendation was made in 1992. Indeed, among many other examples, it appears from reports to the Board of Governors (BoG) that in 1998 Iran concluded a contract with a supplier in the Russian Federation related to the delivery of equipment for laser enrichment at the undeclared AVLIS facility in Lashkar Ab'ad. It would have been useful for the Agency to be aware of these deliveries as it was the opinion of Agency experts that the system at Lashkar Ab'ad, as designed and reflected in the contract, would have been capable of HEU production had the entire package of equipment been delivered. The Secretariat, in an August 2006 Note has recommended that States should now provide information on their past nuclear activities. It is important for the Agency not only to be systematically informed both by the exporting and the recipient States of future transfers of the items listed in Annex II of the AP, but, in order to fill the gap of the past, to be informed of all such transfers that have taken place at least since the recipient state joined the NPT.

There are, however, reasons to doubt that the Board of Governors will adopt such recommendations any time soon.

However, the Director General (DG) could circulate a note to all Member States wherein he would draw their attention to the fact that the above mentioned information is most valuable for the Agency to fulfill its mandate and that the Agency expects Member States to provide such information under Article VIII.A of the IAEA Statute, which states that each member should make available such information as would, in the judgment of the member, be helpful to the Agency. It would also be useful for the DG to confirm that Member States should provide to the Agency information on export denials and aborted procurement enquiries for items listed in Annex II of the AP.

## Conclusion

Over the next 20 years a considerable number of new electrical nuclear power plants are likely to be constructed and start operation around the world. This prospective market is already attracting competition among a few large suppliers. This healthy competition should not be engaged in at the expense of stringent safety, security and non-proliferation standards. Recent nuclear cooperation agreements concluded by exporting countries without explicit non-proliferation conditions such as having an Additional Protocol in force are a matter of great concern. If the Nuclear Suppliers Group, under the pressure of some of its powerful members, agrees to disregard its present export rules for what the US has unilaterally defined as the “special case of India,” I am afraid that the non-proliferation regime will be weakened precisely at a time when it should be strengthened.

What is most important is to make constructive and politically acceptable proposals to correct the anachronistic limitations and loopholes contained in the NPT and Safeguards Agreements. In the present political environment any attempt

to amend the NPT or Comprehensive Safeguards Agreement or the Additional Protocol would be doomed to failure and most likely counter-productive. One should expect many NNWSs to be irritated and to perceive these attempted changes as intensifying discrimination against the nuclear have-nots. For that reason, one should avoid any measure that could be seen as unduly penalizing states in good standing with their safeguards undertakings because a couple states have violated their commitments. This is why the generic UNSC resolutions proposed in this address deal exclusively with the case of NNWSs that have been in non-compliance with their safeguards agreements. A rule-based regime defeats itself if it does not embrace reasonable enforcement measures such as these.

The international community, too often, has the unfortunate tendency of waiting for a crisis to occur before taking corrective actions instead of drawing the lessons from previous crisis and taking preventive measures in order to diminish the risk of their reoccurrence. The international community knows what should and could be done to diminish the risk of nuclear proliferation. If we do not act now there will be a renaissance of nuclear weapons proliferation. The future depends on us.

Finally, I would like to take this opportunity to express my gratitude to the Safeguards Department, with its 600 staff members from 86 nations, whose extraordinary dedication and teamwork has resulted in many improvements and successes.

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*These contributions have not been peer-refereed. They represent solely the view(s) of the author(s) and not necessarily the views of APS.*

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## Preserving the Hanford B-Reactor: A Monument to the Dawn of the Nuclear Age

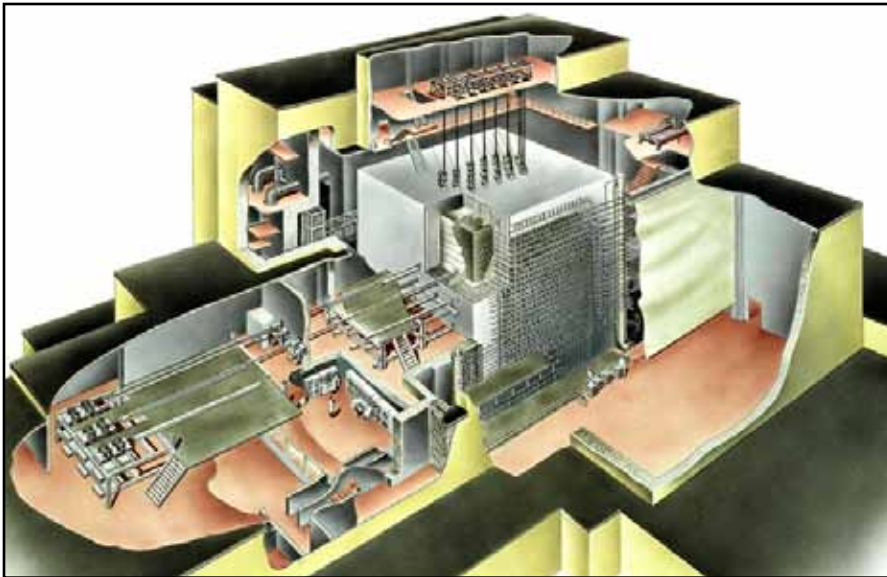
*Robert F. Potter*

September 2009 marked the 65<sup>th</sup> anniversary of the startup of the world’s first industrial-scale nuclear reactor, the Hanford B Reactor. Designed and constructed within 22 months of Enrico Fermi’s first demonstration of a self-sustaining chain reaction, B Reactor produced plutonium for the Trinity Test and for the “Fat Man” nuclear weapon dropped on Nagasaki.

Unfortunately, as many of the facilities constructed for the Manhattan Project have been demolished or are off-limits to the general public, subsequent generations have lost valuable

opportunities for learning about the history and impact of the Project. Since 1991, an all-volunteer group, the B Reactor Museum Association (BRMA), has worked with local and federal authorities to preserve B Reactor as a public museum. The reactor building and its contents are being restored to reflect their appearance as they were during operation, and exhibits reflecting the history of the Hanford site are being added. In this article I describe the history of B Reactor and BRMA’s preservation efforts.





*Cutaway diagram of a Hanford reactor. Illustration supplied by the author.*

## **B Reactor Construction and Operation**

Based on the success of Fermi's CP-1 pile, General Leslie Groves approved the Hanford Engineer Works site in southeastern Washington state for plutonium production in January 1943. Under design, engineering, construction and operations supervision of the DuPont corporation, a massive construction project promptly began on that remote 670-square mile reservation. The accompanying photograph, which shows just one of three wartime reactor sites at Hanford, gives an idea of the immensity of the project.

With its 250 MW thermal power output, B reactor was designed to produce sufficient plutonium for a nuclear weapons arsenal by itself, but duplicate D and F Reactors were also authorized to provide additional production capacity. [Editor's note: At a power output of 250 MW thermal, a reactor fueled with natural uranium produces about 190 grams of Pu per day; the bare critical mass of Pu-239 is about 15 kg.] B reactor was constructed between October 1943 and September 1944.

The reactor buildings were 120 feet wide by 150 feet long and 120 feet tall. They were built on 23-foot thick concrete foundations, with quarter-inch steel plate set into the concrete and later welded to the outside walls of the reactor to form a gas-tight enclosure to keep circulating helium gas in. Helium was chosen for the reactor atmosphere because it was chemically inert and did not absorb neutrons [See Ref. 1 for a detailed description of the construction and engineering of the reactor.] The core of each reactor comprised more than 75,000 individually-machined graphite moderator blocks measuring approximately 4 inches square by 48 inches long and weighing 50 to 60 pounds each. The finished graphite pile was 36 feet wide by 36 feet tall by 28 feet front to back. As shown in the accompanying cutaway diagram, the core was

surrounded by thermal and biological shields; the former comprised 10-inch interlocking cast iron blocks on all sides of the reactor to capture much of the radiation which escaped from the core, and the latter was a 50-inch thick sandwich of alternating layers of steel and Masonite designed to further reduce radiation to acceptable operating levels.

The core contained 2004 aluminum process tubes to hold the reactor fuel. These tubes ran from front to rear through the thermal and biological shields and the core. Each tube held 32 aluminum-clad cylindrical fuel elements, each approximately 1.5 inches in diameter by 8 inches long. A full fuel load was 64,000 elements. Each process tube had removable end-cap assemblies at the front and rear faces of the reactor to provide access for refueling

and connection to the cooling system. Cooling water was taken from the Columbia river, purified, and pumped in a single pass through the tubes. Nine control rods entered from the left side of the reactor. Operators in the control room (to the lower left of the reactor in the cutaway diagram) could adjust these rods remotely to start the reactor and subsequently increase, decrease, or stabilize the reaction rate or shut the reactor down altogether if necessary. Twenty-nine vertical safety rods entered from the top of the reactor. Each of these was suspended above the reactor to a winch that was locked by an electromagnetic clutch. In the event of a power failure or other emergency, the clutch would release and the rods would drop into the core to shut down the reactor.

The first fuel was loaded into B Reactor by Enrico Fermi on September 13, 1944. Criticality was achieved with only 1,500 tubes loaded on the evening of September 26. As is well-known, the reactor shut itself down within a few hours due to Xenon poisoning, a situation which necessitated a significant delay in order to add fuel to the additional process tubes and to plumb the tubes into the cooling system. Full 2,004-tube criticality was achieved on December 28, 1944. The first "official" shipment of irradiated fuel elements from B Reactor was processed on December 26, 1944, and the first small batch of plutonium nitrate was transferred by DuPont to the Corps of Engineers on February 5, 1945. This plutonium was taken to Los Alamos and used in the Trinity Test. In the months that followed, the B, D, and F Reactors produced the plutonium that was used in the "Fat Man" bomb. In describing the pioneering nature of the plutonium project, General Groves wrote that "It was a phenomenal achievement; an even greater venture into the unknown than the first voyage of Columbus." [2]

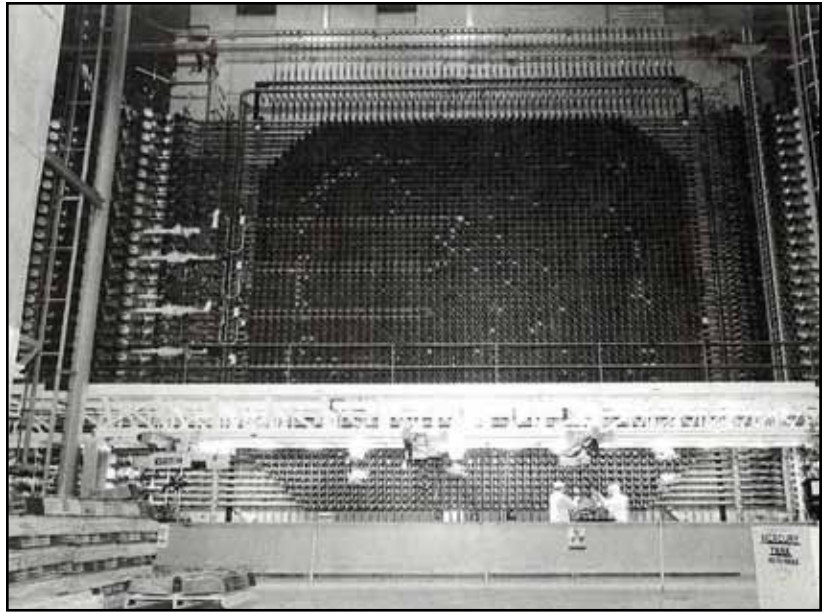
## B Reactor in the Cold War & Beyond

After World War II, six more reactors were built and operated at Hanford to produce materials for America's nuclear weapons program. B Reactor operated for more than 20 years, finally being shut down for good in February 1968. While designed to operate at 250 MW, B Reactor was operated at levels that exceeded 2000 MW, with the only major modification being an increase in the cooling water capacity from 30,000 to 70,000 gallons per minute – a stunning tribute to the strength of the original design.

All nine of the reactors at Hanford were shut down by October 1989. That year, the primary mission of Hanford was changed from producing weapons material to cleanup of the waste that was the legacy of more than 40 years of material production. The new cleanup mission has two regulatory drivers: the U.S. Environmental Protection Agency (EPA)'s Superfund *National Priorities List* (NPL) and the *Tri-Party Agreement* between the EPA, the U.S. Department of Energy (DOE), and the State of Washington Department of Ecology. The NPL requires compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLA established regulatory requirements for cleanup of the site, including the decommissioning of the Hanford reactors, but it also provided a possible regulatory path for preserving B Reactor. The Tri-Party Agreement includes legally binding milestones for the cleanup of the site over the next few decades.

The possibility of B Reactor being decommissioned and demolished became the catalyst that focused the community on preserving B Reactor. In 1991, a small band of local supporters organized the B Reactor Museum Association (BRMA), a non-profit corporation dedicated to educating the public about the historical and technological significance of B Reactor by working to ensure its preservation and making it available to the public as a museum. Many of the more than 100 BRMA members spent their careers at Hanford; some helped to build and operate B Reactor and were present when Fermi directed its start-up.

BRMA's initial activities included amateur lobbying, letter-writing, disseminating information, making presentations to civic and social organizations, participating in community activities, and establishing a working relationship with DOE to become a stakeholder in the future of the Hanford Site. Since the mid-1990's BRMA has provided tour guide services for DOE visitors and for DOE-approved escorted public tours of the reactor. In 1999, BRMA was contracted to prepare the Historic American Engineering Record (HAER) for B Reactor, an in-depth look at the design, construction, and



Front face of B-reactor. Photo supplied by Ruth Howes.

operation of the reactor. This document was submitted to the National Park Service to be included in the HAER archives in the Library of Congress and is available online [1].

In, 1993, DOE issued a Record of Decision (ROD) for the final Environmental Impact Statement for the decommissioning of the shut-down Hanford reactors. The ROD directs that the reactors will be placed in interim safe storage for up to 75 years, during which time monitoring, surveillance, and minimum maintenance will be performed. The 75-year safe-storage period would be followed by final demolition and disposal of the reactor blocks. Interim safe storage for the reactors, called “cocooning,” includes demolition of the reactor building down to the shield walls and installation of a safe storage enclosure roof; the remaining shield wall becomes part of the enclosure. Cocooning of the first of the reactors began in 1995; to date, five have been cocooned, with the other three scheduled to be completed by 2015.

In response to community interest in preserving B Reactor, DOE delayed the decision on the final interim safe storage option for B Reactor. In 1999, DOE issued the ROD for the *Final Hanford Comprehensive Land-Use Plan*, with a preferred alternative that includes B Reactor as a possible museum and the surrounding area available for recreational support activities. To address the museum alternative and to meet CERCLA requirements, DOE conducted an Engineering Evaluation/Cost Analysis (EE/CA) for an interim removal action for B Reactor to support escorted public access. The result of the EE/CA was an Action Memorandum issued in 2001 by the EPA that authorized DOE to perform hazards mitigation within the reactor and to provide for public access to the reactor along a tour route designated in the EE/CA for up to 10 years. DOE subsequently invested more than \$3

million for hazard mitigation, including monitoring to ensure safe radiation levels. All work on the reactor must be done in compliance with the National Historic Preservation Act of 1966 and the approval of the Washington State Historical Preservation Office. With the upgrades complete, DOE increased the number of scheduled escorted public tours of the reactor. More than 8000 visitors have toured B Reactor since 2001; at this writing, an additional 5000 visitors are scheduled to visit during 2009.

BRMA was a principal driver in establishing a local Coalition for B Reactor Preservation in 2005. The Coalition includes representatives from BRMA; the Tri-Cities Economic Developmental Council and Visitor and Convention Bureau, the Columbia River Exhibition of History, Science and Technology, and the Hanford Reach National Monument Heritage and Visitor Center. The Coalition has significantly increased the effectiveness of the grassroots effort to preserve B Reactor with the local DOE Office, DOE headquarters, and Congressional delegations.

The Coalition has received significant support from the Atomic Heritage Foundation (AHF), a Washington-based nonprofit organization dedicated to preserving the history of the Manhattan Project and its legacy. The Coalition joined with AHF to obtain a \$350,000 grant from the M.J. Murdock Charitable Trust of Vancouver, Washington, to fund multimedia interpretive exhibits that were installed in B Reactor in 2007. These include audio-video vignettes accompanied by a computer-generated model of the reactor, archival photos, movie footage, filmed statements by Manhattan Project veterans, and a cutaway scale model of the reactor. Also located throughout the tour route are self-standing storyboard panels that describe the operation of various reactor systems.

A further initiative that may significantly impact the future of B Reactor is the “Manhattan Project Special Resources Study” currently being conducted by the National Park Service (NPS). This study was authorized by an act of Congress in 2003 which directed the NPS to evaluate the creation of a multi-site unit of the National Park System at Manhattan Project sites in Oak Ridge, Los Alamos and Hanford. BRMA has been working closely with the NPS Seattle Regional Office on the study, providing input for evaluating the suitability, feasibility, and possible management options for B Reactor to be included in the National Park System. The report on the results of the study is scheduled to be submitted to Congress by the Secretary of the Interior by the end of this year (2009), and will recommend how to preserve Manhattan Project facilities and identify the management resources necessary to make them available to the public. Follow-on Congressional action will presumably provide the direction and means necessary to preserve these facilities.

Finally, B Reactor was placed on the National Register of Historic Places by the NPS in 1992. In 2005, BRMA submitted a draft application to the NPS Seattle Office for B Reactor to receive the nation’s highest designation for a historic property, that of a National Historic Landmark. Following receipt of review comments from the NPS Program Office of National Register of Historic Places and National Historic Landmarks, the NPS Seattle Office took the lead in preparing and submitting the final application and sponsoring the nomination before the Landmark Committee. After more than two years of reviews and hearings, the Secretary of the Interior designated B Reactor as a National Historic Landmark in August 2008. This is a significant achievement: less than 3% of sites on the National Register ever get elevated to Landmark status.

BRMA and the Coalition for B Reactor Preservation feel that we are close to reaching our goals of preserving this historic marvel of science and making it available to the public. There are lessons that have been learned that will continue to serve us well as we go forward and can serve as guides for others involved in similar projects:

- Clearly define and stay focused on your objective. Plan and execute actions that directly address your objective – don’t waste time and resources doing things that don’t advance your cause.
- Know and understand the regulatory requirements that impact your project, and use them to your advantage.
- Maintain effective and open communications with all levels of local, state and federal governments and the regulatory agencies that are involved in your project. Find and work with at least one advocate for your project within each of those organizations.
- Build a broad base of community and political support.
- For projects that involve Federal agencies, involve support from your Congressional delegation and their staff.
- Don’t lose patience – the wheels of government grind slowly and are largely beyond your control.

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- [2] *Leslie R. Groves, Now It can Be Told (1962; reprint DeCapo Press, Inc., 1983), p. 38.*

*Robert Potter is a retired Project Manager with Bechtel Corporation with 30 years of experience in the nuclear industry, including more than 15 years at the Hanford Site. While at Hanford, Potter’s responsibilities included surveillance and maintenance of retired plutonium production reactors (including B Reactor) and management oversight for the decommissioning of five of those reactors. Potter is a member of the BRMA and is co-chair for public relations. Information on BRMA’s activities can be found at <http://www.b-reactor.org/museum.htm>*

*These contributions have not been peer-refereed. They represent solely the view(s) of the author(s) and not necessarily the views of APS.*

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## Global Warming: Lessons from Ozone Depletion

*Art Hobson*

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My teaching and textbook have always covered many physics-related social issues, including stratospheric ozone depletion and global warming [1]. The ozone saga is an inspiring good-news story that's instructive for solving the similar but bigger problem of global warming. Thus, as soon as students in my physics literacy course at the University of Arkansas have developed a conceptual understanding of energy and of electromagnetism including the electromagnetic spectrum, I devote a lecture (and a textbook section) to ozone depletion, and another lecture (and section) to global warming. Humankind came together in 1986 and quickly solved, to the extent that humans can solve it, ozone depletion. We could do the same with global warming, but we haven't and as yet there's no sign that we will. The parallel between the ozone and global warming cases, and the difference in outcomes, are striking and instructive.

The ozone story begins in 1928 when the General Motors Corporation first synthesized chlorofluorocarbon (CFC) chemicals [2]. Being chemically inert, nontoxic, non-corrosive, nonflammable, and gaseous at atmospheric pressures but liquid at high pressures, these compounds of chlorine, fluorine, and carbon made perfect refrigerants and other products. By 1986, CFCs were a \$700 billion (annually, in today's dollars) industry for the production of Freon, aerosol spray propellants, plastic foam blowing agents, and solvent cleansers for electronic equipment. The post-World-War-II U.S. air-conditioning revolution that moved much of our population from the northeast to the southwest was based on CFCs.

CFCs created lots of business and little fuss until 1974, when scientists began asking where all these inert gas molecules might be drifting. Being inert, essentially all the CFCs manufactured since 1928 should still be in the atmosphere. But where? And what became of them there? During decades of profitable production, nobody had thought to ask.

In 1974, University of California-Irvine chemists Mario Molina and Sherwood Roland hypothesized, based only on theories and laboratory experiments and not on atmospheric measurements, that CFCs could remain in the atmosphere for decades, slowly drifting upward until reaching the stratosphere 10 to 50 km overhead. At that altitude, high-energy solar ultraviolet radiation should eventually split CFC molecules apart, releasing chlorine into the stratosphere. Chlorine reacts strongly with ozone,  $O_3$ , to form ClO and  $O_2$ . In the strato-

sphere, ClO would then be bombarded by ultraviolet radiation to release the chlorine, which would then be free to destroy another  $O_3$  molecule. In this way, each chlorine atom destroys about 100,000 ozone molecules. This could be a disaster. Because ozone shields Earth's surface from most of the sun's high-energy ultraviolet radiation, humans and most other life could not survive without it.

This set off an international debate, analogous to today's global warming debate. Environmentalists argued for a protective CFC ban in order to be safe rather than sorry, while industry argued that the science was uncertain and a ban would cost money and jobs. In further analogy to the global warming debate, developing nations argued that they should be exempt from CFC restrictions because the problem had been caused by industrialized nations and the underdeveloped nations had not yet had time to benefit from CFCs. In 1978, a consumer boycott led to a U.S. ban on CFC spray-can propellants, but other CFC applications persisted, as did the debate.

Early in 1986, a comprehensive year-long international scientific study involving 150 scientists from many nations concluded that CFCs and related substances in the atmosphere had doubled since 1973 and could pose a real threat. This study was analogous to the reports of the Intergovernmental Panel on Climate Change (IPCC) that have now appeared four times since 1990. But unlike the IPCC reports, and despite the lack of direct atmospheric evidence of harm to atmospheric ozone, industry took this report quite seriously. In September 1986, after 12 years of opposition to CFC restrictions, an alliance of 500 U.S. CFC producer and user companies unexpectedly issued a statement supporting international regulation of CFCs. The industry group's chair stated that the scientific assessment had changed industry's evaluation and that "large future increases in CFCs would be unacceptable to future generations." This announcement was greeted with consternation by European CFC users and producers.

Following this U.S. industry turnaround, things changed almost instantaneously. Environmentalists, scientists, the United Nations Environmental Program (UNEP), the Reagan administration, a U.S.-led international coalition of nations, and the U.S. chemical industry led by the Dow and Du Pont Corporations, took unified, strong, and swift action. Between December 1986 and September 1987 four rounds of UNEP-sponsored conferences drew up the world's first international

environmental treaty, the Montreal Protocol. The treaty took effect on 1 January 1989 with ratifications from nations representing 83% of global CFC consumption.

This remarkable treaty transformed a nearly trillion dollar international industry by mandating the complete abolition of CFCs and several related chemicals by year 2000. Furthermore, the treaty granted China, India, and other developing nations an extra ten-year grace period to produce and consume CFCs, and mandated financial and technical assistance to underdeveloped nations to compensate them for their missed opportunity to benefit from the decades of CFC use that industrialized nations had enjoyed.

Today it might seem surprising that large business interests and the conservative Reagan administration cooperated with scientists and environmentalists to draw up and approve such a treaty, especially in the absence of direct evidence of harm to stratospheric ozone. It's a good thing they did. Even with the treaty, the U.S. Environmental Protection Agency (EPA) estimates that 200,000 Americans have died or will die from skin cancers associated with excess ultraviolet radiation brought about by CFC-caused ozone destruction.

Surprisingly, the discovery of the "ozone hole"--a large region of depleted stratospheric ozone over Antarctica--had no effect on the Montreal negotiations or the Montreal Protocol, although it did have an effect on later supplements to the Protocol. A British Antarctic survey team under Joseph Farman published the first report of the ozone hole in 1985. Susan Solomon followed this up with the first U.S. National Ozone Expedition in 1986, confirming the ozone hole's existence and announcing evidence that CFCs were the cause. But there was little scientific consensus about any of this until six months after a second U.S. expedition in September 1987, and the perplexing and controversial new discoveries had no effect on the Montreal negotiations [2]. It is remarkable that this prescient treaty was drawn up based primarily on laboratory experiments and chemical theories, in the absence of clear and direct evidence of what was happening in the atmosphere. Somehow, the world managed to agree on a strong treaty based on possibility of harm, even though the science was highly uncertain.

We now know that, without the treaty, ozone depletion would have been much worse by now, with millions contracting skin cancer, glaucoma, and other diseases. The atmospheric concentration of the destructive element, chlorine, recently leveled off at about 4 parts per billion and is expected to decline to the supposedly safe level of 2 ppb by 2050. Notice that chlorine is measured in parts per billion, yet it was putting the planet at risk. The atmosphere is surprisingly complex and delicate. Without the Montreal Protocol, chlorine concentrations would have soared to over 13 ppb by 2010. In

recognition of their contribution to the Ozone Treaty, Molina and Rowland, along with Paul Crutzen, who did similar work dealing with nitrogen compounds rather than CFCs, received the 1995 Nobel Prize for Chemistry for having "contributed to our salvation from a global environmental problem that could have catastrophic consequences."

Within the Reagan administration, conservative ideologues such as Secretary of the Interior Donald Hodel debated this issue with realists such as Deputy Assistant Secretary of State for Environmental Affairs Richard Benedick. Luckily, the realists won. Benedick was the chief U.S. negotiator of the treaty.

In his excellent book *Ozone Diplomacy* recounting the story of ozone protection, Richard Benedick lists several reasons for success [2]. First and foremost was the indispensable role of science. In addition to theories and discoveries, the best scientists and the most advanced technology had to be brought together to build an international scientific consensus. Close collaboration between scientists and government was crucial. Scientists had to assume shared responsibility for the policy implications of their findings. The implication for today, when there are so many science-related social issues, is that scientists should devote more of their attention to such interdisciplinary issues as global warming, nuclear weapons proliferation, harmful pseudoscience, energy efficiency, etc.

Second, a scientifically well-informed public was a prerequisite to mobilizing the political will of governments and industry. The media played a vital role in bringing the issue before the public. Both the UN and the U.S. government undertook public education campaigns. The implication for educators is obvious: In our science courses, we need to teach the related social implications.

Third, the UNEP was indispensable in mobilizing data, informing public opinion, bringing governments to the bargaining table, and providing an objective international forum. The implication is that international scientific and environmental organizations, including the non-governmental organizations (NGOs), are crucial to solving global science-related social problems, and deserve our support.

Fourth, U.S. leadership made a major difference. The U.S. government set a good example by being the first to take action against CFCs. It developed a global plan for protecting stratospheric ozone and campaigned tenaciously for it. The EPA labored tirelessly to develop analyses of all aspects of the problem. The U.S. Department of State capitalized on the expertise of the EPA and the National Aeronautics and Space Administration. The implication is that a powerful nation, or perhaps a group of nations such as the European Union, is needed to help lead the way on international environmental issues.

Why did Dow, Du Pont, and other companies begin to support CFC restrictions in 1986, despite their 12-year history of opposition to regulation? First, the chemical industry was sophisticated enough to understand and take seriously the scientific realities expressed in the 1986 international scientific study. Second, they had the good business sense to see that their interest lay not in continuing to fight the science but rather in joining the scientific realists to ban CFCs. They knew that refrigerants, spray propellants, and such would always be in demand, and that Dow and Du Pont could be leaders in developing the new ozone-friendly versions of these chemicals.

Today, the evidence that global warming is a looming catastrophe caused by fossil fuels is far more compelling than was the 1986 evidence that ozone depletion was a looming catastrophe caused by CFCs. The global warming evidence was compelling at least by the time of the IPCC's Third Assessment Report (TAR) in 2001, which stated for example that "the current rate of [CO<sub>2</sub>] increase is unprecedented during at least the past 20,000 years," that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities," and that "temperature increases are projected to increase by 1.4 to 5.8°C over the period 1990 to 2100 [3]." In view of the 33°C natural greenhouse effect, and the 40% anthropogenic increase in CO<sub>2</sub> (the second most important greenhouse gas, after H<sub>2</sub>O) since 1800, it is almost a no-brainer to conclude that temperatures should have increased by a few degrees due to human activities [4]. Yet the fossil fuel industry, the automobile industry, and others continue fighting tooth and nail against responsible action.

During 1989 to 2002, for example, industry sponsored an anti-scientific campaign known as the Global Climate Coalition to persuade congress and all Americans that global warming was non-existent. These forces dominated the Bush administration during 2000 to 2008, which worked consistently to misrepresent and disregard global warming science [5]. Today, Congress is barely able to pass any legislation, no matter how weak, to regulate carbon dioxide emissions.

In analogy with the ozone campaign in 1986, one might expect that the U.S. would lead the international effort against global warming. But far from leading, we have refused for 8 years to join other industrialized nations in this effort.

In analogy with the ozone campaign, one might expect that the fossil fuel industry would take seriously the excellent science of the four IPCC reports and recognize that its interest lies in accepting the science of global warming and joining in regulating greenhouse gas emissions. After all, people will continue to need energy services, and there will be plenty of business opportunity in switching from fossil fuels to efficiency, renewable energy sources, nuclear power, and in sequestering carbon dioxide emissions. But the fossil fuel industries have not really embraced these options, and have fought realistic steps to restrict greenhouse gas emissions.

In analogy with the ozone campaign, one might expect that the United States would be willing to grant the developing nations leeway in reducing their emissions, in recognition that they have not had the two centuries we have had to take advantage of fossil fuels, and that their current per capita emissions are far lower than ours. Yet many in the U.S. congress ignore these arguments, insisting that developing nations be subject to the same total national percentage emissions reductions as the industrialized nations.

Progress against global warming will continue to be impossible without the kind of cooperation from the fossil fuel industry that the world had from the chemical industry in fighting ozone depletion. Will that cooperation be forthcoming? Some would say that Earth hangs in the balance.

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- [5] See, for example, the Union of Concerned Scientists' Survey of Federal Climate Scientists (2006), available at [www.ucsusa.org/scientific\\_integrity/abuses\\_of\\_science/federal-climate-scientists.html](http://www.ucsusa.org/scientific_integrity/abuses_of_science/federal-climate-scientists.html).

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# COMMENTARY

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## Stimulating Renewable Energy Education in the U.S. and Beyond: One 72-year-old Physicist's Second Career

*Robert Ehrlich*

This commentary explores reasons why many four-year institutions have not mounted undergraduate programs in the important area of renewable energy until recently, and it suggests ways to overcome the obstacles which continue to exist. Although the author's teaching experience in the renewable energy area is currently nil, he has developed and is scheduled to teach such a course in spring 2010, and he has learned some important lessons while preparing to do so. In a concluding section he describes a web site he created to assist any other faculty new to the renewable energy field who seek either to develop their own courses and programs, or merely to integrate such material into their regular courses.

As of mid-2009, there are around 15 Bachelor's-level programs in the U.S. with renewable energy or some variant thereof in their title; there appear to be even fewer at the graduate level. While the pace at which new programs in this field are being introduced appears to be accelerating, it seems curious that only perhaps one percent of colleges and universities have renewable energy bachelor's programs despite the strong student interest in the subject and the need for graduates in the workforce. As one measure of the slowness of higher education in responding to the need, consider that it was not until 2004 that the second renewable energy bachelor's program in the U.S. appeared.

### **Obstacles to new renewable energy programs and the need to mount them**

Developing any new undergraduate program can be costly both in terms of money and time, and it represents a long-term commitment by an institution. A prudent institution will want assurances that a proposed new program will not simply attract the same students who would have, in its absence, flocked to one of its existing under-enrolled majors. This concern is expected to be especially acute for a program proposed in a "hot" but untested area such as renewable energy, where one might worry whether its popularity might be fleeting and not be able to deliver the number of expected majors over the long-term. It will be recalled, for example, that in the early 1980's a plethora of courses on energy were created, which disappeared once the nation's concern about the "energy crisis" abated. It is argued here that our "energy crisis II" is not going to dissipate so easily, and that student interest

in renewable energy could do for science (and physics in particular), what Sputnik did in the early 1960's.

Even so, the concern that developing an entire new major in renewable energy might be unwise is supported by some limited polling data the author has done. Despite the strong interest of many of today's students in the field of renewable energy, these data suggests that many undergraduates might not view a degree in renewable energy as a "real" major like mathematics, English, or engineering. For all the above reasons, many institutions have entered the field gingerly, choosing only to offer renewable energy tracks within existing programs, or alternatively, to introduce them as minors rather than majors. The latter choice is the course of action that George Mason University has decided to undertake for now — see: <http://cos.gmu.edu/academics/undergraduate/minors/renewable-energy>

Whatever the programmatic structure (new major, minor, or track in existing program) the worry that renewable energy will prove to be a passing fad is, however, almost certainly unwarranted. Given the current challenges the world faces in the areas of the three E's (energy, environment, and economy), most scientists and policy makers are convinced that we will need to make the transition to renewable energy as rapidly as practical. Supporters of renewable energy now include many movers and shakers in the public and private sectors. These range from former energy executive T. Boone Pickens to internet giant Google, which has started a solar-energy company, e-solar. E-solar relies on a solar-thermal process that can actually use solar energy to produce electricity at night! Google co-founder Larry Page has expressed the view that within 20 years solar power could produce all the world's energy needs. On a shorter time span, Google says its goal is to produce one Gigawatt of renewable energy — enough to power the city of San Francisco — more cheaply than coal-generated electricity. The company has predicted that this can be accomplished in "years, not decades." [1]

The field of renewable energy is strongly interdisciplinary, and currently most professionals in the field have their undergraduate training in a traditionally science or engineering-related subject. Disciplinary-based training in science or engineering for those going into renewal energy research may be appropriate, but here we argue that there is also a role for undergraduate interdisciplinary programs in renewable



energy – as perhaps a minor instead of a major. For example, a student wishing to pursue a career in marketing, law, IT or public policy relating to renewable energy could well benefit from such a minor.

There is another argument for undergraduate programs and courses in renewable energy that has particular saliency to those of us in the physical sciences concerned about the high attrition rates in our subjects. The ability of renewable energy to capture student’s imaginations and motivate them can be an important means of drawing students into our fields and keeping them there. Thus, renewable energy can serve as an important recruiting vehicle for challenging subjects such as physics, which many students might avoid initially. But such efforts need to be done in an honest way, since students will see through any marketing ploy in which standard courses having little to do with renewable energy are repackaged as part of stitched-together program. An honest move by an institution into the renewable energy area can be daunting from a variety of perspectives, especially from that of individual faculty who have spent their whole career teaching in other areas – I know since I am one!

## Physics courses on renewable energy, and finding resources to teach them

Last year, after having spent the preceding half century in teaching physics, I realized that there is nothing more important for me to work on in my remaining years on this planet than renewable energy education. I began modestly enough by proposing a new course on the physics of renewable energy which would build on some basic knowledge of physics, rather than being an introductory survey course. Such introductory survey courses are also valuable, but they serve a somewhat different (less mathematically sophisticated) audience. The physics course I developed (at the 300 or junior level) uses calculus, builds on freshman/sophomore physics, and shows students how to do calculations so as to investigate the performance of various renewable energy systems. I did contemplate a more general course on energy (not just renewables), except I think topics like nuclear energy if treated seriously are deserving of a separate course

Putting together my course was made more difficult by my lack of knowledge of available resources. In well-established fields such as physics there are a plethora of standard text-



books, but what could I use as the text in a physics of renewable energy course [2]? Very few options seemed available given the course level and my desire for end-of-chapter assignments. Likewise, how could I find out about places to visit in my area for field trips? Who could I contact for occasional guest lectures? Where could I find good sets of simulations and demonstrations? Where could I find out about student internships, student projects, and last but not least, how could I find a good set of lecture notes I could build on?

Although I was able to rely on my own knowledge or a modest amount of Googling for some of the preceding resources, others proved far more problematic. These difficulties led me to realize that many other faculty new to the renewable energy area might have the same problem, and that I could have a positive impact on renewable energy education far beyond my own institution by providing a central clearinghouse for all such resources. This was the germ of idea for the “rev-up.org” web site which I started in Spring 2009. Rev-up stands for renewable energy valuation and understanding project, and the acronym reminds us of the need to rev-up our efforts in this important area.

## What are the unique features of the rev-up.org web site?

Virtually all existing web sites dealing with renewable energy education, including the excellent one maintained by the Department of Energy, are controlled by some central authority – a fact which has both positive and negative features, depending on the resources, attention, biases and knowledge of the central authority. However, such web sites can never be as responsive to user’s needs as those of the web 2.0 variety, i.e., those which are interactive and modifiable by users. I wanted rev-up to be modifiable by the community of users in the manner of Wikipedia, and it should also offer some of the social-networking capabilities available in Facebook and

MySpace. As with Wikipedia, rev-up has moderators that prevent abuses, such as the posting of blatantly incorrect, obscene, or defamatory information.

Rev-up currently provides users with information on twelve categories of resources related to renewable energy education. These include: books, media, places to visit, speakers, simulations, demos & kits, college programs, student projects, research, internships, career information and course notes. Users are free to sort, download, add content, edit and review existing entries. For example, it is a trivial matter for users to find speakers, places to visit, or internships within some specified miles of their location. It is equally trivial for users to add themselves or their institution to the database of speakers, or to that for internships, research, college programs, etc. In addition to querying the database or adding new items, users can easily upload images and videos, such as a film of an interesting renewable energy field trip they took. Users can also post questions or answer other’s questions. Naturally, the site encourages users to propose changes to the basic structure, including the possible addition of new categories of resources, and other ways to encourage renewable energy education – especially at the secondary and postsecondary levels. Thus, rev-up.org is a work in progress that continually evolves to meet the needs of users.

## References

- [1] *Reported in the November 28, 2007 New York Times.*
- [2] *Eventually, I settled on an excellent text: “Renewable Energy Resources,” by Twidell and Weir (Taylor & Francis, 2005).*

*Robert Ehrlich chairs the physics and astronomy department at George Mason University. In 2009 he contracted with a company (Sakshi Infoway Ltd) to build a web site to his specifications, and he created the non-profit rev-up corporation to administer the site. Bob gives talks on workshops on the need for physicists to get more involved in renewable energy and on his rev-up.org web site. e-mail: rehrlich@gmu.edu*

*These contributions have not been peer-refereed. They represent solely the view(s) of the author(s) and not necessarily the views of APS.*

*Physics and Society* is the non-peer-reviewed quarterly newsletter of the Forum on Physics and Society, a division of the American Physical Society. It presents letters, commentary, book reviews and articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. **Opinions expressed are those of the authors alone and do not necessarily reflect the views of the APS or of the Forum.** Contributed articles (up to 2500 words, technicalities are encouraged), letters (500 words), commentary (1000 words), reviews (1000 words) and brief news articles are welcome. Send them to the relevant editor by e-mail (preferred) or regular mail.

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# OPPORTUNITIES

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## **Assistant Professor (Research) Position in Technology Policy**

In connection with the emerging emphasis on Science, Technology, Peace and Public Policy at Wayne State University, the University seeks a talented multi-disciplinary scholar to conduct research on the technology-policy nexus related to such concerns as energy, the environment, national and international security, health or economic development and to teach related courses in the Department of Electrical and Computer Engineering. The position will be housed in the Department of Electrical and Computer Engineering and will report to the Department Chair and to the Director of the University's Center for Peace and Conflict Studies in the College of Liberal Arts and Sciences. Initial appointment to this full time non-tenure track position can extend up to three years, with annual reviews by the Department and Center, and may be renewable. For additional information about the participating units, see their web sites at: [www.ece.eng.wayne.edu](http://www.ece.eng.wayne.edu) and [www.clas.wayne.edu/pcs/](http://www.clas.wayne.edu/pcs/), or contact Dr. Yang Zhao, ECE Department Chair [[yzhao@eng.wayne.edu](mailto:yzhao@eng.wayne.edu); 313-577-3920].

The candidate should possess a doctoral degree or equivalent in an appropriate discipline. Salary is commensurate with credentials and experience. Applicants must apply through the University's electronic human resources system and only online applications will be accepted. To apply, search for ECE Department at <http://jobs.wayne.edu> and upload application materials under Assistant Professor-Research position. Review of applications will begin immediately and continue until the position is filled. The expected starting date is Fall 2010. Further information on Wayne State and its programs may be found at [www.wayne.edu](http://www.wayne.edu).

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## **AIP Mather Public Policy Intern Program**

*We reproduce here part of the text of an AIP-FYI release of November 11, 2009. The full text can be found at <http://www.aip.org/fyi/2009/135.html>*

The American Institute of Physics (AIP) and the John and Jane Mather Foundation for Science and the Arts announced today (November 11, 2009) the creation of the AIP Mather Public Policy Intern Program. "The aim of the program is to promote awareness of the policy process among young scientists by directly engaging them in the work that goes on in the federal government -- work that is today as exciting as in any time in the past," explained AIP Executive Director and CEO Fred Dylla.

John Mather, who shared the 2006 Nobel Prize in Physics for his precise measurements of the primordial heat radiation of the Big Bang and who is now a senior astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, MD, reached out to AIP to explore the development of this new initiative to expand hands-on policy opportunities for physics undergraduates. The program is funded through the John and Jane Mather Foundation for Science and the Arts, itself funded by Dr. Mather's Nobel award. Dr. Mather hopes that this internship program will "get students interested when they still have an opportunity to learn about government process in their formal education; grad schools tend to expect their technical students to concentrate on technical things."

The AIP Mather Public Policy Intern Program will expand on the already successful Society of Physics Students (SPS) internship program which places physics undergraduates at federal agencies in and around Washington, DC. AIP Mather Public Policy Interns will contribute science expertise to congressional offices or other locations where public policy is developed. Like other SPS interns, each AIP Mather Public Policy Intern will receive advice and guidance from practitioners in their offices, AIP mentors, and the accomplished network of present and former AIP Congressional Fellows. According to SPS Director Gary White, Mather internships are intended to be 9.5 week summer experiences for undergraduates in which they spend time on Capitol Hill addressing specific policy and legislative issues. Applicants for the AIP Mather Public Policy Intern Program must have an exceptional scholastic physics background and potential for future success, be active in SPS activities, have experience or demonstrable interest in public policy, and be able to communicate clearly and effectively, both orally and in writing. Further information for applicants will be available this winter, and will be publicized by FYI.

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## REVIEWS

### **Evolution vs. Creationism: An Introduction, 2nd ed.**

*Eugenie C. Scott. Greenwood Press, Westport, CT, 2009, xxvi + 351 pages, ISBN 978-0-313-34427-5*

### **But Is It Science? The Philosophical Question in the Creation-Evolution Controversy, Updated ed.**

*Robert T. Pennock & Michael Ruse, eds. Prometheus Books, Amherst, NY, 2009, 577 pages, ISBN 978-1-59102-582-5*

Biological research has it all over creationist watching when it comes to advancing human knowledge. But those of us who study the evolution of creationism have one great advantage: We can actually identify every event in the selection process that drives the evolution. The natural selection elucidated by Darwin has its creationist-watching analogue in judicial selection, and we can follow in exquisite detail the evolution of creationism in the changing environment of judicial opinion.

The bare historical chronicle is simple enough. The 1925 Scopes “monkey” trial was sufficient persuasion for the craven textbook industry; all mention of evolution disappeared from most high school biology textbooks for the next four decades. But when the 1957 Sputnik scare sparked public interest in science education, the NSF-funded Biological Science Curriculum Study (BSCS) produced excellent texts. Inevitably, evolution took its proper role at the center of the science, and pervaded the entire curriculum.

But in four states, teaching evolution was still illegal. In 1965, Arkansas teacher Susan Epperson sued, arguing that the law made it impossible to do her job properly. In 1968 the U. S. Supreme Court struck down the anti-evolution laws. The court ruled that they promoted a particular religious view in violation of the First Amendment.

Faced with this new legal environment, creationism evolved. “Creation science” soon appeared, purporting to teach a history of the universe—and particularly of life on Earth—entirely consistent with the first few chapters of Genesis but supposedly entirely independent of it. The universe was created roughly 6000 years ago in six calendar days. The creation included all the “kinds” of creatures now alive or having become extinct since then. The geological and paleontological records were almost entirely laid down by Noah’s Flood, which took place about 1500 years after the creation. This “model,” it was asserted, was at least as effective as the evolutionary, old-universe “model” in accounting for the total body of scientific observations.

Laws were proposed widely, and passed in Arkansas and Louisiana, requiring that equal time be afforded to teaching both “models” in public schools. The Arkansas law was struck down in Federal district court in 1982, in *McLean v. Arkansas*. The U.S. Supreme Court followed with a definitive 7-2 opinion striking down the similar Louisiana law in *Edwards v. Aguillard* (1987). Again, the courts saw through the thin veil and found it obvious that creation science was sectarian religion masquerading as science.

The courts thus recognized that creation implies a creator and that creators are supernatural—and likely divine. In response, new species of creationism found ways to avoid the God-word. Of these species, the most prominent was “Intelligent Design,” the earliest fossils of which appear about 1984. But just as a long time elapsed from the appearance of the first mammals to their domination of the continents, intelligent design creationism (IDC) was inconspicuous until law professor Phillip Johnson published *Darwin on Trial* in 1991. Subsequently, IDC came to dominate the public face of the creationist world, but suffered a serious setback with the “catastrophe” of the 2005 *Kitzmiller v. Dover* decision.

Accompanying the long evolution from Scopes onward, a vast creationist literature appeared. It was countered by an extensive literature describing the countless failings, falsehoods, and impossibilities of creationism in all its forms. Among the latter works were the first editions of the two fine books reviewed here. The rapid evolution of IDC during the period leading up to and following on *Kitzmiller* has spurred the publication of updated editions, which I will now discuss.

The creationist movement is complex, dynamic and replete with deliberate attempts to mislead the outsider. The movement has broad repercussions in the worlds of politics, education, philosophy, and religion. Hence, an initial inquiry into the current situation and its historical background can be confusing. *Evolution vs. Creationism* is a superb introductory guide through the tangle, whether the reader wishes simply to get a clear basic picture of what is going on and what one might expect in the future, or plans to dig further into the subject. Author Scott writes with crystal clarity and punctilious fairness. She never gets bogged down in excessive detail and yet never sacrifices accuracy to brevity. She is the long-time Executive Director of the National Center for Science Education, the national clearinghouse for teaching good science (and especially evolution). Hence she has, and skillfully conveys, a bird’s-eye view of the world of creationism.

The second edition, expanded by about one-third, is divided into three parts. Part I introduces the basic ideas and

methodology of science and sketches the role of evolution in the historical sciences. It quickly focuses on biological evolution, describing the history of life through deep time and describing the role of natural selection (while pointing out that other mechanisms exist as well). Such concepts as adaptation, speciation, adaptive radiation, and cladistics are set forth briefly but very clearly. The “tinkering” nature of the evolutionary process is described. In the following chapter, the author sets forth the broad spectrum of religious belief, especially in America. In doing this, Scott emphasizes the implications of belief for the creation-evolution spectrum. That spectrum ranges from flat-earthers and geocentrists through young-earthers and progressive creationists (who believe that God created living things by multiple interventions, consistent with their appearance in the fossil record), to various types of religious and non-religious evolutionists.

Part II sets forth the history of the creationism/evolution controversy. There is a brief sketch of its history from ancient times through the publication of *Origin of Species*, followed by a discussion of the scientific and religious reactions to *Origin* in Europe and America. There follows an account of the rise of fundamentalism in the early 20<sup>th</sup> century, and its absorption of creationism.

Scott gives a brief but lucid description of the rise and fall of the various species of young-earth creationism through its heyday from Scopes to *Edwards v. Aguillard*. A largely rewritten chapter describes the rise of neo-creationism, from the now nearly forgotten “abrupt appearance” strategy of creationist lawyer Wendell Bird to the better known IDC.

IDC asserts that living things are too complex to have evolved. Thus their existence is evidence of an Intelligent Designer. To satisfy the courts, the latter *just possibly could be* a space alien or even a Flying Spaghetti Monster. But the ID folks make it clear to friendly audiences that the Intelligent Designer is the God of the King James Bible, and none other. (As theologian-mathematician William Dembski has put it, “Intelligent design is just the Logos theology of John’s Gospel restated in the idiom of information theory.”)

There is a fine discussion of the two major “scientific” arguments of IDC – biochemist Michael Behe’s “irreducible complexity,” as exemplified by the mousetrap, and Dembski’s logically hopeless “explanatory filter.” The latter, girded about by much fallacious information theory, is an unintentionally comic attempt at a recipe for detecting miracles.

The central role in the IDC movement of the Seattle-based Discovery Institute and its Center for Science and Culture is discussed briefly. I would have liked to see some discussion of the Center’s Wedge Strategy, which places IDC in the context of a much larger program of restructuring all of American culture and life along fundamentalist lines. But this

would perhaps have involved straying from the main subject of the book, and in any case the Wedge Strategy is thoroughly covered in Forrest and Gross’ *Creationism’s Trojan Horse* (Oxford University Press, 2003.)

Scott then turns to the recent legal history of creationism, with emphasis on the 2005 *Kitzmiller v. Dover* trial. Judge Jones’s opinion was a thumping legal finale to several years of scientific, philosophical, and theological publications that had demolished the assertion that ID is science. But creationism does not cease to evolve, and its proponents have since moved to a fallback position with some success. In the current approach, school boards are urged to require the teaching of the “strengths and weaknesses of evolution,” or the “evidence against evolution,” or to “teach the controversy [*sic*].” Sometimes other subjects unpopular with the political or religious right, such as embryonic stem-cell research or global warming, are thrown in as well. To date, the strategy has worked in Louisiana and Texas, though it has failed in several other states.

Part III consists of seven chapters. The first five comprise excerpts giving creationist positions and anti-creationist rebuttals in astronomy, cosmology, geology, biological evolution, legal matters, science education, religion, and the nature of science. In the chapter on the nature of science, Scott sets forth the creationist argument that over the past few centuries science has wrongly rejected the study of supernatural events (miracles), together with rebuttals. All excerpts are brief and some are very fair paraphrases of publications whose authors have denied Scott permission to quote. Taken together, the excerpts give a lively picture of the debate.

The final chapter summarizes media treatment of evolution and creationism, and surveys of public attitudes among nations and among U.S. population segments. One could hope for a more cheerful picture.

*But Is It Science?* is a more specialized treatment of creationism, a sort of source book edited by two distinguished philosophers of science. Both have had frontline experience as expert witnesses in two key creationism trials: Ruse in *McLean v. Arkansas* and Pennock in *Kitzmiller v. Dover*. Though their main intent is to provide a philosophical framework for evolution-vs.-creationism, they have assembled essays that provide a fine historical, scientific, religious, and legal background.

Part I begins with the major source materials of creationism and evolution. For creationism these are the Bible—in particular Genesis and John I—and the “watch implies a watchmaker” arguments presented extensively and eloquently by William Paley in 1802. Evolution is represented by the magisterial final chapter of *On the Origin of Species*.

Nineteenth-century objections to evolution are represented by British geologist Adam Sedgwick and American

theologian Charles Hodge. These are balanced with a representative passage by “Darwin’s bulldog,” Thomas H. Huxley. Of four 20<sup>th</sup>-century essays, the most interesting is one by philosopher Karl Popper, who is best known for his requirement that a statement need be falsifiable if it is to be scientific. Popper, whose background lay largely in the physical sciences, raised a philosophical furor when he made the assertion

I have come to the conclusion that Darwinism is not a testable scientific theory, but a *metaphysical research program*—a possible framework for testable scientific theories.

Though this was by no means a rejection of evolution, it was taken as such by the creationist community. A lengthy philosophical dispute, much of which is quoted in this book, led eventually to acquiescence by Popper and most of his school that evolution is indeed a scientific and not a metaphysical endeavor. Not surprisingly, this change of heart has been ignored in the creationist literature.

Part II centers on creation science. An essay by Ronald Numbers, author of the definitive history *The Creationists* sets the stage. A piece by young-earth creationist Duane Gish sets forth the “two-model” approach of creation science, and it is demolished in Ruse’s testimony and Judge Overton’s decision in *McLean v. Arkansas*. Judge Overton used the concept of falsifiability in his determination that creation science is not science. Philosopher of science Larry Laudan, who has written extensive criticism of demarcation—the problem of distinguishing scientific from nonscientific activity—took issue not with the decision but with Judge Overton’s argument. Three essays by Laudan are accompanied by refutations by Ruse and philosopher Barry Gross.

Part III brings the book more or less up to date by describing the rise and decline, but not the fall, of IDC. Special attention is devoted to *Kitzmiller*, and a portion of Judge Jones’s opinion is given. But the most original and (I think) interesting essay in Part III is the insightful piece by Nick Matzke, now a graduate student in integrative biology but at the time a staff member at the National Center for Science Education.

Matzke shows in painstaking detail that for all its claims, IDC is nothing more than a rephrasing of creationism with some changes of emphasis. All the arguments by Phillip Johnson and the Discovery Institute predate his association with the movement. Even the terms of art associated with IDC, such as “intelligent design,” “non-religious creator,” “design theory,” and “irreducible complexity,” are first seen in the works of creationists who were trying to rephrase “creation science” in a way that would circumvent the *McLean* decision. As Matzke clearly shows, even Johnson’s major political contribution to creationism—the “big tent” that embraces both young- and old-earth creationists—was already in place by

1984. And Dembski’s vaunted “specified complexity” is nothing more than a rehash of the earlier assertion that evolution violates the second law of thermodynamics. As Matzke puts it so neatly, “The creationists...like to claim that evolution only occurs within strict limits. In biology, this is false; but in the evolution of creationism, it applies in spades.”

*Evolution vs. Creationism and But Is It Science?* are outstanding additions to the large literature on the creationist movement in all its aspects. They are not, of course, the end of the story by a long shot. Although one might hope third-edition updates of these works will not be necessary, that is not likely to be the case. Matzke quotes an ACLU lawyer, who said at the end of the *McLean* case in 1982, “Don’t think the creationists will go away. They won’t! They’ll just regroup and be smarter and sneakier next time.”

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*These contributions have not been peer-refereed. They represent solely the view(s) of the author(s) and not necessarily the views of APS.*

## **Energy, Environment, and Climate**

Richard Wolfson (*W. W. Norton & Co., Inc., New York, 2008*)  
ISBN 978-0-393-92763-4. 532 pp. \$69.47 (paper).

*Reprinted with permission from American Journal of Physics, © 2008, American Association of Physics Teachers.*

Courses in energy and the environment are now offered by many U.S. secondary schools and colleges. Wolfson is a Professor of Physics at Middlebury College where he also teaches environmental studies, and his textbook for such a course is the fourth that I know of that is aimed at college non-science students [1]. All of these textbooks are “conceptual,” meaning that they use little or no algebra even though they are strongly quantitative in their use of numbers, proportionalities, graphs, powers of ten, percentages, and probabilities. They all begin with a brief presentation of the physics that will be needed for the remainder of the book, presentations that are too brief to allow the book to qualify as a “physics” textbook but that are usually sufficient to provide the background needed for a textbook limited to energy-related topics. Wolfson’s book uses somewhat more algebra than the other books, to the point that many non-science students may be distracted and put off.

Wolfson also differs from the other authors in offering a slightly more substantial serving of physics in the opening chapters. However, I must quibble with the way he defines the central concept of “energy.” Wolfson’s strategy (p. 22) is to ask students to do deep knee bends for a few minutes, at a rate of one knee bend per second, and to then inform them that “your body is working at the rate of about 100 watts.” This gives students an intuitive, yet quantitative, feel for the

watt, and power. He then (p. 37) describes “energy” as “the ‘stuff’ that makes everything happen,” and quantifies this notion with the statement (p. 50) that “if you use energy at the rate of one watt for one second, you’ve used one joule of energy.” This seems an unnecessarily roundabout way to define energy. The other three books, after defining “work” as the exertion of a force through a distance, just come right out and say that energy is the capacity to do work. This is the correct, complete, and most easily understood definition of this important word.

Quibbles aside, this is a very good book. What I like best about it is its emphasis on global warming (Wolfson prefers the term “climate change” but I’ve always preferred “global warming” as equally accurate scientifically, and more direct). A textbook needs one or more unifying themes, and global warming—which might well turn out to be the overarching theme of this century—is perfect for a book on energy and the environment. This theme is introduced at the beginning of the book, re-appears at several points, and fully occupies the last five of the book’s 16 chapters.

One of many nice details in these five chapters is a quantitative comparison of the greenhouse effect on Venus, Earth, and Mars. Wolfson uses the Stefan-Boltzmann radiation law and the known rate at which solar energy reaches these planets to calculate average temperatures at the three planets’ surfaces, neglecting the greenhouse effect. He then notes that the observed surface temperatures exceed the calculated temperatures by 503°C, 33°C, and 0°C, respectively. This excess is the greenhouse effect, and the three values accord nicely with the observed facts that Venus has a thick atmosphere heavily laden with the greenhouse gases H<sub>2</sub>O and CO<sub>2</sub>, Earth’s atmosphere has a more modest amount of these two greenhouse gases, while Mars has very little atmosphere and even less greenhouse gas. These values also show students that a planet’s atmosphere, and its greenhouse gases in particular, have a major influence on climate.

Wolfson gives a good presentation of the workings and results of the Intergovernmental Panel on Climate Change. Among those results are estimated values of the natural and anthropogenic “forcings,” or changes in the amount of solar energy reaching Earth’s surface, measured in W/m<sup>2</sup>; major sources of global CO<sub>2</sub> emissions; the “global warming potential” of the various greenhouse gases, relative to CO<sub>2</sub>; the carbon cycle; feedback mechanisms that can dampen or amplify the forcings; Earth’s temperature during recent times and over hundreds of thousands of years; nuclear isotopic methods of reconstructing the long-term CO<sub>2</sub> concentration and temperature records; the evidence that humans are at least partly to blame for the recent temperature rise; and much more. His presentation of the various IPCC scenarios and

future projections based on them is especially enlightening.

The final section titled “Strategy for a Sustainable Future,” is a welcome and heartening presentation of the Socolow-Pacala “wedge strategy” describing some 15 different ways to combat global warming, all based on plausible near-term technology such as carbon capture and storage [2].

The book’s central block of 7 chapters covers the various energy resources: fossil (2 chapters), nuclear, geothermal and tidal, direct solar, indirect solar (water, wind, biomass), and a chapter on “hydrogen” in both of its senses: nuclear fusion, and the “hydrogen economy” based on the chemistry of hydrogen. These chapters are uniformly well done; they could have benefited from a careful definition of, and greater use of, the all-important concept of “sustainability.” At the end of the book, Chapter 16 includes an excellent discussion of energy efficiency and conservation, but I think this big topic deserves to be treated as a major source of energy services and to be included as a separate chapter with the other energy sources, right along with direct solar etc.

The pedagogy is quite adequate. The writing is relaxed, personable, and good. The details are correct, insofar as I was able to check them. The text does not emphasize “inquiry” methods, although as in any textbook the end-of-chapter questions could be considered inquiry. Each chapter includes a review of the “big ideas,” terms students need to know, about 10 review questions, about 15 quantitative but non-algebraic exercises, and about four “research problems” that involve library or internet research and, frequently, numerical calculations or estimations.

Any textbook worth its salt should teach something new to the course instructor, and to reviewers. Indeed, I learned several things, such as the distinction between series and parallel hybrid vehicles (p. 120), the meaning of a “combined cycle” power plant (p. 124), a gravitational analogy to nuclear fusion (p. 345), and the comparison of Venus, Earth, and Mars referred to above. It’s an excellent, carefully written, and highly relevant textbook, with a welcome emphasis on global warming—a topic that should in my opinion be part of every introductory physics course.

- [1] *The other three are Energy: Physical, Environmental and Social Impact*, Gordon J. Aubrecht (Pearson Prentice Hall, Upper Saddle River, NJ, 2006), 3rd ed.; *Energy: Its Use and the Environment*, Roger Hinrichs and Merlin Kleinbach (Thomson Brooks/Cole, Belmont, CA, 2006), 4th ed.; *Energy and the Environment*, Robert A. Ristinen and Jack J. Kraushaar (John Wiley & Sons, Inc., 2006), 2nd ed.
- [2] Robert H. Socolow and Stephen W. Pacala, “A Plan to Keep Carbon in Check,” *Scientific American*, September 2006, pp. 50-57.

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