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PHYSICS & SOCIETY

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Editor's Comments

Sixty-five years ago this summer, the fruits of the Manhattan Project burst upon the world, helping to bring a swift end to the most brutal war in history. As evidenced by the New START arms control agreement recently signed by the United States and Russia, we continue to deal, decades later, with the legacy of that time. In this issue of *P&S*, Pavel Podvig expertly summarizes the key provisions of the treaty in one of our three feature articles. A related Commentary by Irving Lerch, former APS Director of International Affairs, offers a perspective, based on personal experience, regarding the issue of what the Treaty does not address: the thousands of tactical nuclear weapons still in existence and distributed around the world. Yet another issue in the nuclear spectrum is that of the spread of enrichment technology that could engender proliferation, and Francis Slakey and Linda Cohen describe what they see as the dangers of the emerging technology of isotope separation by laser excitation. The pros and cons of these pressing and complex issues are part of what our national leadership must deal with. By happy circumstance our third feature article, by Richard Muller, describes his experience at teaching a course at Berkeley titled "Physics for Future Presidents," from which he has developed two successful books; one of these was reviewed in our October 2009 edition. Our News of the Forum summarizes many interesting papers that were presented at the Society's March meeting held in Portland, OR. Eugenie Mielczarek's Commentary in our April edition on the purported healing effects of magnetic field and other alternative medical practices generated two letters. New NSF guidelines for ethics components of grant applications is the subject of a Commentary by Marshall Thomsen. We reprint an AIP FYI article on Congressional hearings on shortages of helium-3, and we also have four very worthy book reviews, two of which deal with the effects of global climate change.

I am pleased to report that a great many back editions of *P&S* have been scanned and are now available on the *P&S* website. These go back to the second year of publication, 1973. As far as I am aware, we lack only a few editions: all from 1972, July 1973, and part of April, 1980. If any readers have these on hand and would be willing to send them to me, I will see that they get scanned and posted, and will return the original to you promptly. An Index of all articles in all editions available on the website has also been posted.

With this edition, we welcome aboard a new member of the *P&S* editorial board: David Harris of SLAC. David is replacing Lee Schroeder, who is rotating off the board and with whom it was a real pleasure to work. As Editor of the Fermilab/SLAC "Symmetry" particle-physics magazine, David brings a wealth of relevant experience to us; I and the other members of the board look forward to working with him.

As ever, enjoy this edition of *P&S*. We look forward to your contributions and feedback. *—Cameron Reed*

FPS-Hosted Sessions at the APS March Meeting

Larry Woolf, Brian Schwartz, and Philip Taylor

The annual APS March Meeting was held in Portland, OR, 15-19 March, 2010. The Forum on Physics & Society hosted or co-hosted three sessions on a variety of topics including interesting middle-school children in science, opportunities for research and employment in transportation science, and Physics, Culture, and the Arts. The following paragraphs briefly summarize the papers presented. The complete scientific program of the meeting can be found at http://meetings.aps.org/Meeting/MAR10/Content/1812.

Session B3: *How to Interest Middle School Children in Physical Science.* This session was co-sponsored with the Forum on Education and was chaired by Lawrence Woolf. The first talk was by Marcia Barbosa (Universidad Federal do Rio Grand do Sul, Brazil) recipient of the Nicholson Medal for Human Outreach, who spoke on "Attracting girls to physics: the itinerant science project." In Brazil, the percentage of women undergraduate physics majors is below 20%. In order to attract girls to physics, a science van was created that visits suburbs as well as the underdeveloped areas of the city. During these visits, children are exposed to the applications of physics to the real world, much of it involving kitchen appliances. They have the chance to manipulate experiments and to learn how they are related to real life technology. After playing with the experiments, they answer a simple questionnaire designed to evaluate how their views about physics have changed due to this experience. When questioned about the change in their perception regarding physics after being exposed to the experiments, the girls showed a more significant change in having a positive perception than did the boys.

The next speaker was Margaret McMahan Norris (Black Hills State University), who spoke on "Introducing Deep Underground Science to Middle Schoolers: Challenges and Rewards." She described how work is in progress to define the mission, vision, scope and preliminary design of the Sanford Center for Science Education (SCSE), the education arm of the Deep Underground Science and Engineering Laboratory (DUSEL), a proposed major research facility of the National Science Foundation. If final funding is approved, DUSEL will be built at the site of the former Homestake Gold Mine in Lead, South Dakota, beginning in 2012. The SCSE is envisioned to serve as a model for the integration of a science education center into the fabric of a new national laboratory. Its broad mission is to share the excitement and promise of deep underground science and engineering at Homestake with learners of all ages worldwide. The science to be pursued at DUSEL, whether in physics, astronomy, geomicrobiology, or geoscience, is transformational and will spark the imagination of learners of all ages. While the SCSE is under design, an early education program has been initiated that is designed to build capacity for the envisioned center, to prototype individual programs, and to build partnerships and community support. One of the more interesting challenges discussed during this talk was the challenge of education outreach for the significant numbers of K-12 students who learn in one-room schoolhouses in rural parts of South Dakota.

The third speaker was Raymond Vandiver (Oregon Museum of Science and Industry), who spoke on "Creating Engaging Science Learning Experiences for Middle School Students Through Museum Exhibits." He related that the science education community recognizes that reaching middle school students is important because this age is often a turning point when students decide not to pursue further math and science education. The Oregon Museum of Science and Industry (OMSI), together with experts in informal science education from the science museum community, has developed exhibits and supporting programming that promote positive attitudes toward math and science learning by providing engaging experiences in meaningful contexts in which students can develop science process skills and see the relevance of science to their daily lives. A key part of science exhibits for middle school students involves design challenges. The presenter brought along a collimated air fan and demonstrated an example of a design challenge where students cut and shaped small plastic cups and tried to make them stay up as long as possible.

Amber Stuver of the LIGO Livingston Observatory then spoke on "Immersing Southeastern Louisiana Middle School Students in Physics at the LIGO Livingston Science Education Center." The LIGO Science Education Center (SEC) is located adjacent to the LIGO Livingston Observatory and brings the excitement of gravitational wave science to Southeastern Louisiana. While the SEC offers programs targeted for middle school students, they also offer programs for students through post-secondary levels, teacher professional development, and the public. Programs are LIGO related inquiry-based activities and include guided investigations in their classroom and free exploration of the more than 40 hands-on exhibits in the exhibit hall (most built by the Exploratorium). Students also get to visit the working LIGO observatory to interact with scientists and to see the science concepts they are learning in action. The LIGO SEC is the result of the unique collaboration between a museum (The Exploratorium), science laboratory (LIGO), university (Southern University-Baton Rouge) and local education agencies (LaSIP and LaGEAR-UP) to scaffold this outreach. The SEC also serves as a test bed for educational research through collaboration with a Tulane University psychology faculty member. New initiatives of the SEC include developing programs of repeated engagement with teachers through professional development and with students through field trips in order to undertake longitudinal studies on the impact of the informal education environment.

Robert Butler of the University of Portland then spoke on "Teachers on the Leading Edge: A Place-Based Professional Development Program for K-12 Earth Science Teachers." Teachers on the Leading Edge (TOTLE) is an Earth Science teacher professional development program featuring Pacific Northwest active continental margin geology. To engage middle-school teachers and students, TOTLE workshops: (1) invite novice learners to geophysical studies of tectonics, earthquakes, and volcanoes; (2) provide access to EarthScope research; and (3) explain geologic hazards as understandable aspects of living on the "leading edge" of the North American continent. Fundamental concepts and observations progress from global patterns, to regional context, and then to local applications. For example, earthquakes are concentrated near tectonic plate boundaries such as the Cascadia subduction zone between the Juan de Fuca and North American plates. Earthquake hazards include liquefaction and landslides that are affected by regional and local geology; relative earthquake hazard maps then provide comparisons of hazards on county, city, and neighborhood scales. Inquiry-based field investigation of coastal ghost forests and Cascadia tsunami geology stimulates learning about Cascadia great earthquakes and tsunamis and provides a case study of scientific discovery. Field studies of volcanic mudflow deposits from Mt. Hood and Mt. Rainier highlight volcanic hazards to rapidly increasing populations that live near recently active Cascade volcanoes. The program emphasizes the importance of infrastructure engineering and emergency preparedness in preventing geologic hazards damage, injuries, and deaths in order to: (1) demonstrate how Geoscience research leads to improved engineering designs that mitigate hazards; (2) align lessons with national and state K-12 science education standards that focus on science, technology, and societal connections; and (3) avoid fatalism and develop a culture of geologic hazards awareness among future citizens of the Pacific Northwest.

Session H8: ***Opportunities for Research and Employment in Transportation Science.*** This session was chaired by Brian Schwartz and featured four talks. The city of Portland and its metropolitan area are considered as one of the most innovative regions in the country with respect to transportation planning, initiatives and implementations. Quite often the planning involves a good understanding of the nature of interacting systems plus techniques on the analysis and modeling of competing social, economic and urban concerns. Papers presented at this session dealt with various of these concerns.

The first talk was entitled "The Science of Transportation Analysis and Simulation." This was presented by John Gleibe, Assistant Professor, Department of Urban Planning at Portland State University (http://www.pdx.edu/profile/meet-professor-john-gliebe). He noted that transportation science involves methods developed to model and analyze the interaction between human behavior and transportation systems. From the human behavioral, or demand, perspective, the interest is in how individuals and households organize their activities across space and time, with travel viewed as an enabling activity. By including constraints of household budgets and land use systems and regional economics and business development, one can develop complex structural econometric modeling systems as well as simulations. From the transportation systems, or supply, perspective, one is interested in the level of service provide by transportation facilities, be it auto, transit or multi-modal systems. This has led to the development of network models and equilibrium concepts as well as hybrid simulation systems based on concepts borrowed from physics, such as fluid flow models and cellular automata-type models. The presentation included representative sample of these methods and their use in transportation planning and public policy analysis.

The second talk was "The Physics of Traffic Congestion and Road Pricing in Transportation Planning," by David Levinson, Associate Professor and Richard P. Braun/CTS Chair in Transportation Engineering, Department of Civil Engineering at the University of Minnesota (http://nexus.umn.edu/), (http://www.ce.umn.edu/people/faculty/levinson/) and (http://nexus.umn.edu/Papers/Cordon-PricingOvercrowding.pdf). The presenter has a background in economics and civil engineering and has published papers on the physics of congestion theory and congestion pricing. Using game theory techniques, with a simple two-player game, he shows that the emergence of congestion depends on the players' relative valuations of early arrival, late arrival, and journey delay. Congestion pricing can be used as a cooperation mechanism to minimize total costs (for N players). To illustrate the concept he presented a solutions for N=7. This model is compared to the bottleneck model. The results of numerical simulation show that the two models yield identical results in terms of lowest total costs and marginal costs when a social optimum exists. Two types of product differentiation in the presence of toll roads, path differentiation and space differentiation, are defined and measured for a base case. The findings favor a fixed-rate road pricing policy compared to complete pricing freedom on toll roads.

The third talk, "The Changing Science of Urban Transportation Planning," was presented by Tom Kloster, Regional Transportation Planning Manager, Oregon Metro (www.oregonmetro.gov, http://web.pdx.edu/~jdill/USP_transportation_alumni.htm#kloster and http://www.greatstreets.org/index.html). Tom is a native of Portland and has worked as a city planner in the Portland area for 18 years. He has been concerned with putting "community" back into city planning. The last half of the 20th Century was the age of the automobile, and the development of bigger and faster roads defined urban planning for more than 50 years. During this period, transportation planners developed sophisticated behavior models to help predict future travel patterns in an attempt to keep pace with ever-growing congestion and public demand for more roads. By the 1990s, however, it was clear that eliminating congestion with new road capacity was an unattainable outcome, and had unintended effects that were never considered when the automobile era first emerged. Today, public expectations are rapidly evolving beyond "building our way out" of congestion toward more complex definitions of desired outcomes. In this new century, Kloster maintains that planners must improve behavior models to predict not only the travel patterns of the future but also the subsequent environmental, social and public health effects associated with growth and changes in travel behavior, and provide alternative transportation solutions that respond to these broader concerns.

The fourth talk, "Trends in Transportation Sciences and How to Get a Job in the Industry," was given by Carl Springer, DKS Associates (http://www.dksassociates.com/dks_about.asp). Carl is a scientist who works in a major transportation planning company with offices throughout the western United States. Originally, transportation sciences were focused on the construction of a national infrastructure of highway facilities. A typical professional in those days was a civil engineer with expertise limited to roadway design, construction and maintenance. Currently, the focus of the profession is much more diverse, encompassing all modes of transport in both rural and urban contexts, and it plays a key role in economic vitality, livability and the environment and thus more diverse talents in science, economics and planning are required. The speaker noted three current trends the affect transportation sciences. First, since the federal interstate system is largely built, there is great interest in developing better understandings of how the system is really used in metropolitan areas, and how to get better value out of it. Second, the movement towards achieving more sustainable urban planning and design requires better models about why people choose to walk, bike, or drive and how they are influenced by accessibility and land uses. Finally, there is a clear trend for putting transportation data in the public's hands to help them better use and evaluate the various transportation modes that are integral to their daily living. Responding to these trends will require new and deeper skills for the transportation professionals including physicists.

Session P7: *Physics, Culture and the Arts.* This session was chaired by Philip Taylor. At the 2009 March Meeting of the American Physical Society held in Pittsburgh, the FPS organized a session on "Physics meets Art" at which physicists described how they used the methods of experimental and theoretical physics to guide our appreciation and interpretation of art. At the 2010 March Meeting in Portland, the tables were turned, and we heard how those involved with the arts perceive the world of physics and physicists.

The first talk was by David Saltzberg from UCLA, who for the last three years has acted as a physics consultant for the producers of the popular television situation-comedy "The Big Bang Theory", which features physicists, astronomers, and engineers as its main characters. In his talk "Physics and the making of "The Big Bang" TV Comedy Series," Saltzberg explained how the girlfriend of one of the main characters was the "eyes and ears of the audience" as she tried to understand what the physicists were talking about. His role as science consultant was to fill in gaps in the script with plausible physics jargon and to correct misconceptions and mistakes. He also provided whiteboards covered with equations in logical order, but was sometimes foiled when these whiteboards were displayed in the wrong order.

The second talk, "Science and Sculpture: Physics, Mathematics and Architecture," was given by Michael Burke, a New York sculptor whose training was in architecture and city planning, but who now strives in his work to combine scientific principles with aesthetic goals. He illustrated his talk with photographs of his work, including an installation in an Etruscan tomb and one at the port city of Savona in Italy. He spoke of "seeing a romance in science equivalent to that of art," and showed us a linear array of sculptures that he has entitled "Quantum Stream."

A different direction was taken by Brian Holmes of the physics department at San Jose State University, whose two-part talk and performance "Understanding Musical Instruments: Composing Updike's Science" embraced "the physics of music and the music of physics." We learned some facts, previously unknown to the majority of the audience, about the way notes are produced in brass wind instruments. The simple formulas for resonating tubes that we teach in elementary physics courses are a cruder simplification and a more inadequate approximation than most of us had imagined. Who knew that the effective length of a trumpet includes a respectable proportion of the anatomy of the trumpeter? Brian then proceeded to introduce Nan Haemer, a soprano, and Terry Nelson, a pianist, who performed some of his settings of John Updike's poems on science. The melodies captured well the essence of the poetry, which tended to reflect an attitude of resignation [Thermodynamics—Lament for Cocoa] or mild rebellion [Chemistry—In Praise of $(C_{10}H_9O_5)_x$]. Updike's mistaken opinion as to the molecular structure of polyethylene terephthalate did not mar our enjoyment.

Getting the Physics right in Portland. *Phil Taylor chaired a jammed Physics and Society session at the APS March Meeting where David Saltzberg explained how he works with the directors of the TV series the Big Bang Theory to make certain that even the white board props have proper physics displayed, and Brian Holmes explained the physics of wind instruments. Then a piece Brian composed for science poems written by the author John Updike was performed by piano and soprano. Later in the meeting at an evening session organized by FPS's Brian Schwartz and Ivan Schuller, James Kakalios educated and entertained the public with his presentation on the Physics of Super Heroes.* PHOTO BY DON PROSNITZ.

Jodi Lomask, director of the Capacitor Dance Company in San Francisco, then spoke on "Art, Science, and the Choreography of Creative Process." Lomask feels that "dance should speak for itself," but broke this rule to present a talk illustrated with movie clips of some of her productions. (She may have set a precedent for talks at the March Meeting, as her presentation followed a warning that her material showed scenes containing nudity.) Jodi's obsession with the mechanics of the human body found expression in a number of remarkable ways; some dancers leaned back against elastic harnesses, while some explored the inside of a spherical frame to depict Earth's convecting interior. She closed with an extraordinarily articulate essay on bringing artists and scientists together to work creatively. It is worth quoting, almost in its entirety:

"It is important for the artist to respect the scientist they work with enough to truly investigate and understand their area of research. The mental discipline this requires is good for the artist. It excites the mind and the act of comprehension stimulates creativity.

"It is important for the scientist who works with artist, to give him space to make his greatest work, without asking the artist to be precise, factual, or accurate – understanding that although the overarching goal of both disciplines may be the same—to locate truths—the process and product for each profession is gravely different and therefore warrants different priorities.

"Scientists become better communicators when they need to explain their work to people outside their field. They also get to consider their research from different perspectives, see it reflected in new ways, which leads to potential creative breakthroughs.

"If scientists are interested in sharing their work with larger non-academic audiences, collaborating on an event-driven art piece is a great approach. The artist can give momentum to an area of research that would otherwise be considered inaccessible to larger portions of the population.

"Artists can help people feel and see what they already know and what is already there but they may have forgotten. As a conduit, as a mirror, as a physical representation, a dancer serves as the embodiment of conceptual space. Work with us and we will enrich each other's process."

Larry Woolf is with General Atomics (Lawrence.Woolf@ga.com).

Brian Schwartz is Professor of Physics at the Graduate Center of the City University of New York (bschwartz@gc.cuny.edu).

His brother Sam, a physics major, was Commissioner of Traffic for New York City, coined the word "gridlock" and runs a major transportation planning company, Sam Schwartz Engineering (http://www.samschwartz.com) and hires physicists.

Philip Taylor is the Perkins Professor of Physics at Case Western Reserve University in Cleveland, Ohio (taylor@case.edu).

Science Committee Hearing Spotlights Shortage in Critical Isotope

[Adapted from AIP FYI #53, May 12, 2010. The original article can be found at http://www.aip.org/fyi/2010/053.html – Ed.]

Severe shortages of helium-3 (He-3) are impacting the production of radiation detection devices, physics and medical imaging research, and oil and gas exploration. This shortage has resulted in a tenfold increase in the cost of this isotope, with users reporting that some suppliers are no longer able to fill orders. Last Month, the Subcommittee on Investigations and Oversight of the House Committee on Science and Technology held a hearing, *"Caught by Surprise: Causes and Consequences of the He-3 Supply Crisis"* on this issue. In the apt words of Rep. Brad Miller (D-NC), "It is astonishing that DOE did not see this coming." This FYI largely focuses on the impacts of this shortage on scientific users.

The Department of Energy is the sole U.S. supplier of this isotope, a by-product from the decay of tritium used to increase the yield of nuclear weapons. Reductions in the U.S. nuclear stockpile have resulted in a diminished supply of He-3 at the same time that demand for it has increased in applications such as radiation portal monitors. It has been estimated that total demand for He-3 in 2009 was 213,000 liters, with only 45,000 liters available. Management of the He-3 program was transferred from the DOE Office of Nuclear Energy to the Office of Science in FY 2009.

William Brinkman, Director of the Office of Science, told the subcommittee "we have reached a critical shortage" in the global supply of He-3. He described how White House staff formed an Interagency Policy Committee in mid-2009 to lower demand and increase available supplies of He-3, and to "optimally allocate" its supply. "The allocation process gives priority to scientific uses dependent on unique physical properties of He-3 and to maintaining continuity of activities with significant sunk costs. It also provides some supply for non-government sponsored uses, principally oil and gas exploration," Brinkman told the subcommittee. Efforts to reduce projected demand in the United States have been successful, dropping from an initial FY 2010 projection of 76,330 liters to 14,557 liters. Although no new allocations will be made for radiation portal monitors, past allotments of He-3 will support the program through "early FY 2011." Brinkman estimated new neutron detection technologies for portal monitors will require two to three additional years of development.

Scientific users of He-3 are pursuing alternative strategies. Brinkman testified that current allocations will support experiments by the U.S. neutron scattering research community through the end of September 2014. Through the end of this decade, new international facilities will require 120,000 liters of new He-3. "The U.S. has insisted that international partners take responsibility for securing new sources of He-3, that the U.S. can no longer be the major supplier satisfying these needs," Brinkman told the subcommittee.

He-3 is required for ultra-low-temperature coolers used in fields such as nanoscience and quantum computing research. The full FY 2010 U.S. cryogenics request was approved. Looking ahead, Brinkman told the subcommittee that "the true impacts to both R&D and operational programs will be better quantified in the upcoming months, as users with small volume requirements place orders for their projects."

Brinkman also discussed developing alternative sources of He-3. In the next three years, reuse and recycling will be encouraged, with efforts to date resulting in a 10 percent overall reduction in demand for new He-3. Laboratories and plants have been directed to inventory unused or excess supplies. The Savannah River National Laboratory is working on a process to extract He-3 from retired equipment, which may yield as much as 10,000 liters.

DOE and the National Nuclear Security Administration are negotiating with countries having heavy-water-moderated reactors such as Canada and Argentina to determine the feasibility of recovering He-3 from permanent storage containers used to store tritium. Technical feasibility and cost studies are scheduled to be complete in early FY 2011, which starts on October 1 of this year. It may be possible to recover 100,000 liters of He-3 through this method over the course of seven years.

Also being studied is extracting He-3 from natural gas, and what Brinkman described as "reactor-based irradiations to produce tritium for the primary purpose of subsequent He-3 harvesting." Both of these longer-term measures will "likely involve a substantial increase in the cost" of the isotope. Finally, NNSA is investigating replacement technologies for neutron detectors that do not use He-3.

Brinkman's written testimony described how He-3 will be allocated in coming years as follows:

"The NSS IPC [National Security Staff Interagency Policy Committee] met in September 2009 and concurred on a strategy that decreases overall demand for He-3, including conservation and alternative technologies, increases supply through exploring foreign supplies/inventories and recycling, and optimally allocates existing supplies. Furthermore, the IPC agreed to defer all further allocation of He-3 for portal

monitors, beginning in FY 2010, and would not support allocating He-3 for new initiatives that would result in an expanding He-3 infrastructure. The IPC stipulated that He-3 requests should be ranked according to the following priorities:

1. *programs requiring the unique physical properties of He-3 have first priority.*
2. *programs that secure the threat furthest away from US territory and interests have second priority.*
3. *programs for which substantial costs have been incurred will have third priority.*

"Adoption of this approach for managing the U.S. He-3 inventory produces allocations for Fiscal Years 2010 through 2017 that can be met by projected reserves. This is in contrast to the original allocation approach, which would have resulted in large and increasing shortages over the same period of time."

Also testifying at the hearing was Dr. William Halperin of Northwestern University and Dr. Jason Woods of Washington University in St. Louis. Halperin, who conducts low-temperature research, told the subcommittee that He-3 shortages "are already creating major difficulties" in advanced materials, metrology and high-speed computation research. Halperin said his research supported by the National Science Foundation, as well as that of other scientists, is jeopardized because of supply shortages. "Many of us are also concerned that without adequate access to helium-three, instrumentation companies may soon be forced out of business." Woods testified about the promise of hyperpolarized-gas MRI to develop more effective drugs to treat lung diseases, and described the impact that shortages will have "on future drug development, efficacy monitoring, and in guiding new surgical and minimally-invasive interventions."

The concluding paragraphs of Chairman Miller's written opening remarks provide both his positive, and negative, reactions to the current situation. They were as follows:

"Good crisis management is an inspiring thing to see in the government and I have to say that the current efforts of DNDO [Domestic Nuclear Detection Office], DOE, DOD and other agencies under the orchestration of the National Security Council staff appears to be very well organized. They have set out to do a thorough survey of demand and have attempted to identify all outlying sources of supply. They are identifying alternative gases and locating international opportunities to temporarily expand the supply of He-3. All of this is laudatory, and can serve as a nice model for future interagency management of crises, but even better is to avoid a situation requiring crisis management in the first place. I hope that DOE has learned a lesson with He-3 that will lead to wiser management of the unique isotopes they control and distribute. "The final lesson I hope the agencies and the White House learn is that when a Subcommittee asks for your documents, you have to produce them or explain why you cannot. The Subcommittee wrote to both the Department of Energy and the Department of Homeland Security on March 8 requesting materials by March 29. Neither agency responded in a timely fashion. Neither agency has produced all of their materials, nor offered anything approaching a comprehensible explanation of the situation. Allegedly, some small set of documents were originally produced by White House staff and distributed to the agencies, and I have been surprised at the difficulty of getting the White House and the agencies to simply do the reviews that the precedents of legislative-executive relations suggest should properly occur for these documents, which do not appear to rise to the level of an executive privilege claim. I am hopeful that we will break this impasse soon. "The implications of the situation are that the Subcommittee is not as prepared for this hearing as we should properly be. The agencies have gone through elaborate fictional inter-agency courtesies allowing for duplicative, time-consuming reviews. There is no legal basis for these reviews. This has not only wasted time but is discourteous to the Committee. As a result, it is my intention to leave the hearing record open and, in consultation with my Ranking Member, Dr. [Paul] Broun [R-GA], to include in the record relevant materials that are responsive to my original letter. I will not rule out a second hearing on this subject if the documentary record contradicts testimony we receive today nor would I rule out taking any other steps necessary to compel production of agency records. I hope it won't come to that, but I had enough of stonewalling and slow rolls by the last Administration to have much patience with it from this Administration."

Richard Jones
Media and Government Relations Division
American Institute of Physics
rjones@aip.org
301-209-3095

LETTERS

In her commentary in the April 2010 *P&S* regarding the idea that electromagnetic (EM) fields from humans can lead to healing, Eugenie Mielczarek rightly says "Silence on this issue by physicists is a serious compromise of the scientific endeavors of physicists relating to medicine and biology." She might have mentioned the award of a 1998 Ig Nobel prize in Science Education to Dolores Krieger, Professor Emerita, New York University, for "demonstrating the merits of therapeutic touch, a method by which nurses manipulate the energy fields of ailing patients by carefully avoiding physical contact with those patients." The associated work (by Rosa et al. [1]) incidentally had one of the youngest authors in a modern paper. Mielczarek also mentions the claims that EM fields and permanent magnets are connected with health. The very same day that I read her Commentary, a local newspaper had a supportive article on magnetic healing. I was the physicist of a duo who wrote an editorial in the British Medical Journal (BMJ) on this topic [2]. To my surprise, the editorial was picked up by newspapers (some good) around the world (even by Al Jazeera, who reported it correctly, in English at least), and we were interviewed by radio stations from abroad. BMJ invites "Rapid Responses" to Editorials, to which the original writer replies. All of these are then published [3]. *Forum* readers are invited to read some of these reader letters, and see (with mingled amusement and horror) that not only laypeople are deceived. I continue to receive items about magnetic healing devices.

We have done experiments, under double-blind conditions, to see if academic physicists could detect magnetic fields at their fingertips, and the results showed no detection [4]. (However, there remains some debate as to whether physicists make a good animal model for humans).

My personal letter to friends, summarizing our BMJ experience, was "don't invest any money in companies that sell magnetic healing devices." In light of Mielczarek's communication, perhaps I should crassly change my advice to "do invest, for profit."

[1] L Rosa, E Rosa, L Sarner, S Barrett, "A Close Look at Therapeutic Touch," Journal of the American Medical Association, 279, 1005-1010 (1998) ; Emily Rosa, "Science Education Prize Acceptance Speech," Annals of Improbable Research (AIR) 5(1), (1999). http://improbable.com/airchives/paperair/volume5/v5il/v5il-toc.html

[2] Leonard Finegold and Bruce L. Flamm, "Magnet Therapy", BMJ 332, 4 (2006).

[3] Responses to [2]: http://bmj.com/cgi/content/full/332/7532/4#responses

[4] Steven Bogh, "Can humans feel static magnetic fields?" Senior Honors Thesis, Drexel University (2007).

Leonard Finegold
Department of Physics, Drexel University
L@drexel.edu, (215) 895-2740

I write to point out an error in the Commentary "Magnetic Fields, Health Care, Alternative Medicine and Physics," by Eugenie Mielczarek on page 16 of the April 2010 edition of *P&S*. Footnote 5 is referenced at the text " ... the web sites of prominent clinics nevertheless market [scientifically unsound] claims." The footnote begins: "Affiliated with Harvard Medical Center is Brigham Young Hospital's Osher Center," and then quotes dubious claims made in course offerings at the Center. But the hospital that hosts the Osher Center is the Brigham and Women's Hospital (as Mielczarek's links make clear); the name "Brigham Young Hospital" appears to be a University. BYU actually has no connection to Brigham and Women's Hospital, and the erroneous name in the footnote may unfortunately tend to associate that university with the unsound claims Mielczarek is reporting.

Alan K. Harrison
Los Alamos National Laboratory
alanh@lanl.gov

Response from Eugenie Mielczarek:

I thank Alan Harrison for pointing out this error. The first sentence of footnote 5 should read: "Affiliated with Harvard Medical Center is Brigham and Women's Hospital Osher Center."

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

Physics for Future Presidents

Richard A. Muller

[Dr. Muller's book was reviewed in the October 2009 edition of P&S. The course he describes here has developed a reputation as "one of the courses you MUST take at Berkeley" and in 2008 and 2009 was voted "Best Class at Berkeley" in a poll taken by the student newspaper – Ed.]

"Physics for Future Presidents" is the name of a course I have taught at Berkeley for the past ten years, as well as the title of the book derived from the course. I created it when I was asked to teach a "Physics for Poets" course at Berkeley. Many of my students have become government and business leaders, and I have high regard for them. They are smart, effective, and in many ways more productive than the typical physics professor. I became convinced that it was not only vitally important to teach these students some "real physics" but also that it could be done in an effective way. Many important issues have physics or high-tech components: energy and alternative energy, nuclear power and weapons, terrorism and counter-terrorism, health, internet, satellites, global warming, remote sensing, ICBMs and ABMs, DVDs and HDTVs. So many people in our government have a poor grasp of science, and yet if they misjudge the science, they can make a wrong decision. My new approach to teaching physics was inspired by this concern and also by the enormous success at Berkeley of an introductory astronomy course by Alex Filippenko that attracted 800 students compared to the meager 35 who signed up for our "qualitative physics" course. What was the difference? Alex showed me his curriculum, and I was amazed to discover that his course had a huge amount of substance, far more than we had in our qualitative physics course. I realized that the way you get students to take physics is to give them a course where they can come away saying "I have really learned something." In this article I will describe my class and the book with the hope that others may wish to use them as models for course offerings of their own.

Too often in the "Physics for Poets" approach professors assume that students can't learn "real physics." We end up talking down to them, rather than treating them as the future leaders many will become. We hide behind the fog of math: Any time a question is too hard, write an equation on the board. Then say that the reason you can't answer it is that the math is too advanced for the student to understand. That's almost always nonsense. The reason that so many students dislike physics is because we are trying to teach them to become mini-physicists, and you can't accomplish that in one semester. Physics is the liberal arts of high technology. PffP (my abbreviation for the course) is designed to attract students and teach them the physics they need to know to make effective leadership decisions.

Can real physics be taught without math? Yes! Math is a tool for computation, but it is not the essence of physics. We often cajole our advanced students, "Think physics, not math!" You can understand light without knowing Maxwell's equations. If a leader needs a computation, they can always hire a physicist. But the knowledge of physics will help them judge, on their own, if the physicist is right.

An anecdote: the ideal student

To illustrate what a student can learn, I like to cite the example of Liz. A year after she took my class she came to see me, eager to share an experience she had had a few days earlier. Her family had invited a physicist over for dinner. He regaled them with stories of controlled thermonuclear fusion and its great future for the power needs of our country. The family sat in awe as this great man described his work. Liz knew about fusion because we had covered it in our class.

There was a period of quiet admiration at the end. Finally Liz spoke up. "Solar power has a future too," she said.

"Ha!" the physicist laughed. "If you want enough power just for California," he continued, "you'd have to plaster the whole state with solar cells!"

Liz answered right back. "No, you're wrong," she said. "There is a gigawatt in a square kilometer of sunlight, and that's about the same as a nuclear power plant."

Stunned silence from the physicist. Liz said he frowned. Finally he said, "Hmm. Your numbers don't sound wrong. Of course, present solar cells are only 15% efficient… but that's not a huge factor. Hmm. I'll have to check my numbers."

That's what I want my students to be able to do. Liz was able to shut up an arrogant physicist who hadn't done his homework! She knew enough about the subject that she could confidently present her case under duress when confronted by a supposed expert. Her performance is even more impressive when you recognize that solar power is only a tiny part of this course. She remembered the important numbers because she had found them fascinating and important. She hadn't just memorized them, but had thought about them and discussed them with her classmates. They had become part of her, a part she could bring out and use when she needed them, even a year later.

The Class: Advanced Physics

PffP is not watered-down physics. It is advanced physics in the sense that it is the physics that most physics majors learn only after finishing their PhDs. It covers interesting and important topics. Students recognize the value of what they are learning, and are naturally motivated to do well. Rather than keep the students beneath the math glass ceiling, I take them above it. "You don't have the time or the inclination to learn the math," I tell them. "So we'll skip over that part, and get to the important stuff right away."

In fact, a typical physics major, even a typical PhD, does not know the material in my book. He or she often knows little about nuclear power or weapons, optics, fluids, batteries, lasers, IR and UV, x-rays and gamma rays, MRI, CAT, and PET scans. Ask a physics major how a nuclear bomb works and you'll hear what they learned in high school. For that reason we have now opened this course for credit for physics majors at Berkeley. In fact, the physics department at Berkeley now recommends that a potential physicist take my course before beginning their major. This is material that typically is not taught in the other courses, and yet it puts the material of the other courses in context.

I made one major concession to my students. They really do want to learn about relativity and cosmology, subjects superfluous for world leadership but fascinating to thinking people. So I added two chapters at the end. They cover subjects that every educated person should know, but they won't help the President make key decisions.

I have email correspondence with every one of my students. That has gotten a bit difficult as the class has grown to over 500 but I've kept it up. Prior to our first meeting I send all students a message and ask them things such as their name, the most advanced physics they have studied, why they are taking the course, and the subject they are most interested in learning about. From the responses, I've discovered that about half of my students have physics dread. They either hate it because they had a bad experience in high school, or they are simply really afraid of it.

Virtually all of my students –by now eight or nine thousand – lost whatever physics dread they had. Most of them have learned to love physics, and they now know that when they don't understand something, it isn't their fault. They have become the "physics expert" to their friends and family. I tell them that if you learn some of this physics you'll go home and start winning arguments with your parents – over nukes, space, alternative energy, terrorism, global warming. The best way to win an argument is not by having a forceful opinion but by having some knowledge. I tell the students that I don't care if they are anti-nuke or pro-nuke; they are going to learn a lot about nukes – nuclear weapons, nuclear power, nuclear terrorism. My course has developed a reputation as "one of the courses you MUST take at Berkeley". In fact, for the past two years (2008 and 2009) in a poll taken by the student newspaper, my course was voted "Best Class at Berkeley." I get students from every discipline, from english majors to music to pre-law and pre-business. I try very hard to keep my own opinions out of the class.

What do the students find most exciting? They love to learn about energy. What does "energy" really mean? What can "alternative energy" do, and what can't it do? They love learning about radioactivity and nuclear weapons and nuclear everything else. They are fascinated with space: what can we really do in space, what is it valuable for, and what is it not useful for. They love the non-partisan view—the facts—about global warming.

Pedagogy

When other faculty look at my curriculum, they are typically amazed that I cover so much. But sometimes when they look closely they are concerned at what I leave out. The concept of "conservation of energy", something all physicists love, is one. I looked at the introductory physics sequence for majors, and discovered that it takes over a year before even math-adept students begin to understand this subtle concept. It is not only hopeless to teach it to non-scientists in one semester, it is counter-productive. The abstract principle of conservation of energy is just not that important for the future president of the United States, who is likely to be much more concerned about the conservation of useful energy.

Here is the quick summary of my approach to PffP; a more complete description is available in the teachers guide to the textbook (available for free to any certified instructor).

1. Immersion. Teach energy not by definition but by examples. This is analogous to learning a foreign language by living in a foreign country.

2. Order of topics. Put most fascinating topics first: energy, satellites, radioactivity, nukes. This motivates and intrigues.

3. Numbers. Work with scientific notation. Math-phobic students are OK with this; it is problem solving with multiple unknowns that frightens them.

4. Understanding. Teach students the relevant science for issues of importance. Enable them to elicit the relevant facts and numbers and concepts when they are needed. Emphasize writing in the exams so that students learn to explain a subject clearly and concisely, with numbers.

5. Respect. Treat the students with the expectation that one of them will someday be a world leader. This is your one chance to teach such a person.

6. Reading and Writing. Liberal arts students love to read. Encourage them read the material over and over, so that lectures do not have to cover everything.

7. Motivation. Emphasize the importance of everything. Pick subjects that stir interest and curiosity

8. Physics as a Second Language. Teach students to use terms correctly. We are teaching "physics as a second language."

9. Multiple levels. Provide some material for those students want more math. I sometimes take five minutes out of a lecture to do some computations, telling the students that the material will not be on the exam. Nearly all the students end up listening to the math approach without the anxiety of having to master it.

10. Politics. Keep your politics from your students. I am proud that students don't know my personal views. When asked about a controversial subject, I do my best to give both sides.

11. What not to teach: How to solve problems using conservation laws. The "scientific method."

12. Question period. For the first 10 minutes, answer questions on any subject. The goal here is partly to answer questions, but also to show students how I handle things I don't know.

13. Fun. Make sure that students are finding the class material riveting. If they don't, it shows in their expressions, and tells me to change my approach, maybe through different examples. I encourage students to share their knowledge with their friends and relatives.

14. Commencement. The physics that can be learned in one semester is tiny compared to how much the students can learn in a lifetime. I discovered that prior to my class, many students didn't pay attention to tech issues. I assign a weekly reading of articles on science, to get them in the habit of reading these articles.

Text: Physics and Technology for Future Presidents

The book comes in two versions. The popular one, "Physics for Future Presidents," is a paperback that's meant to be a page-turner, read by the general public. For a course, students like to have more structure: they want it broken into segments, to have summary sections and problems, questions for further thinking, things they can research on the internet, places where they can get more information, samples of essay questions, multiple-choice questions—the sorts of things that are likely to appear on exams. For that, I've written a hard-back textbook, "Physics and Technology for Future Presidents." The longer title is mostly to distinguish it from the paperback. This textbook contains about twice as much material as the popular version. An accompanying manual for the professor not only has an answer key but relates much of the experience I've had and the lessons I've learned: What kind of homework and quizzes work best? What are the tricks to really appealing to the nervous student? It gives several of the exams I've used in the class. It has plenty of flexibility; there are lots of sections, and most of them can be easily skipped at the discretion of the teacher. Naturally, the course is somewhat cumulative: you have to know about energy before you can discuss nukes or global warming. But if you want to cut out the section on space and satellites, or the one on "invisible light" (IR, UV, x-rays) you can do that with no significant harm.

Bottom Line

The ultimate goal is to have both elected and electorate be scientifically literate. I have tried to create a course that does not depend on me or my own personal experiences or style of teaching. The course might be intimidating to a potential professor, since so much of it is unfamiliar. But the material is fun to learn. Much of the material in this course was new to me when I began to put it together. I didn't know the energy density of batteries, or of gasoline. I wasn't particularly familiar with the levels of radioactivity needed to cause cancer, or with the detailed data that is used to support arguments on global warming. Now I know these things. I encourage others to give it a try. It is a lot of fun to teach, and I continue to learn. The students love it, and that makes teaching this course very rewarding. Part of the joy I get in teaching this class comes from just looking at the students: they don't appear stressed out but rather have their eyes wide open, trying to understand this stuff. Part of the joy comes from interacting with students who attend my office hours with their list of questions. They've discovered that they can understand it, and so they really want to.

Richard A. Muller
UC-Berkeley, ramuller@lbl.gov

New START Treaty and Beyond

Pavel Podvig

The New START Treaty signed by presidents of Russia and the United States in April 2010 in Prague will define the nuclear disarmament process for the next decade and possibly longer. The treaty became the first U.S.-Russian arms control agreement that attempted to create a legal and institutional framework of nuclear reductions that would reflect the new international security environment and that would provide a foundation for deep reductions of nuclear arsenals. Unlike its predecessors—the START II Treaty of 1993, which never entered into force, and the Moscow Treaty of 2002, which was essentially a political declaration—New START contains a mechanism that would provide accountability in the nuclear disarmament process while dispensing with the often overly rigid requirements of the START Treaty that was signed by the United States and the Soviet Union in 1991 and that reflected the substantial degree of mistrust that still existed at the end of the cold war. The New START arguably does not go far enough as far as numerical reductions of nuclear arsenals are concerned since the levels specified in the agreement are only slightly below of what the two nuclear powers have in their arsenals today. However, the treaty will play an important role in maintaining the momentum of nuclear reductions and in keeping open the dialogue between Russia and the U. S. Potentially, the framework of the new agreement would allow other nuclear weapon states to join the process, although this step would require additional effort.

Ratification of the new treaty might present a certain challenge, especially in the U.S. Senate, where it would have to secure support of Republican senators. However, opponents of the treaty so far have not identified any serious flaws in the agreement and the administration is determined to support the ratification process by committing substantial resources to the modernization of the strategic forces and nuclear complex – about $180 billion over the next decade. As a result, it is likely that the treaty will get approval in the Senate. In Russia, the parliament may raise some questions as well, but the Duma will probably follow the example of the U.S. Senate.

Today, the nuclear arsenals of the U. S. and Russia include more than 90 percent of all nuclear weapons in the world. The U.S. government announced in May 2010 that it has 5,113 nuclear weapons in its active arsenal. Of these, 1,968 are operationally deployed strategic nuclear warheads; the rest are tactical nuclear weapons and warheads in active reserve. Russia has never disclosed the exact size of its nuclear arsenal, but estimates done by the Federation of American Scientists show that it has up to 2,600 deployed strategic warheads, about 2,000 tactical warheads, and some number of reserve warheads as well. In addition to these, each side has a substantial number of intact weapons that are awaiting dismantlement, so the total number of warheads is estimated to be as high as 9,600 in the United States and 12,000 in Russia.

The New START treaty will limit only one component of these arsenals: operationally deployed strategic warheads. The treaty will also limit the number of strategic launchers, which comprise land-based intercontinental ballistic missiles (ICBMs), sea-launched ballistic missiles (SLBMs), and strategic bombers. The central provisions of the treaty require the United States and Russia in seven years after the treaty enters into force to reduce their arsenals to

> 700, for deployed ICBMs, deployed SLBMs, and deployed heavy bombers;
>
> 1550, for warheads on deployed ICBMs, warheads on deployed SLBMs, and nuclear warheads counted for deployed heavy bombers;
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> 800, for deployed and non-deployed ICBM launchers, deployed and non-deployed SLBM launchers, and deployed and non-deployed heavy bombers.

The focus on strategic weapons and their delivery systems is a legacy of the traditional arms control process, which has so far dealt mostly with these systems. Tactical nuclear weapons, as well as warheads in reserve or in the dismantlement queue, are harder to deal with and it would take the United States and Russia some additional effort to come to an agreement on those.

Although the limits established by the treaty are relatively high, the U.S. and Russia would have to undertake some steps to bring their forces in line with its requirements. At the same time, both countries made sure that the key components of their strategic arsenals and the modernization programs will not be affected by the treaty.

The U.S. strategic forces today include 450 Minuteman III ICBMs, most of which carry one nuclear warhead. The U.S. Navy operates 14 Ohio-class submarines, each carrying 24 Trident II SLBMs. Two of these submarines are in overhaul at any given time, so there are only 288 deployed SLBMs. With four warheads on each missile on average, they carry a total of about 1,100 warheads. In addition, the United States has 60 bombers that are certified for nuclear missions, 44 B-52Hs and 16 B-2s. These bombers have about 450 nuclear

Estimated nuclear arsenals in 2010 and after the New START reductions *(deployed warheads, New START counting rules)*

	UNITED STATES		RUSSIA	
	2010	***New START***	***2010***	***New START***
ICBMs	550	420	1,250	550
SLBMs	1,100	960	448	640
Strategic bombers	60	60	76	76
Total Warheads	**2,000**	**1,440**	**1,774**	**1,266**

warheads assigned to them: air-launched cruise missiles on B-52Hs and gravity bombs on B-2s.

Most of the nuclear warheads in the Russian strategic arsenal are deployed on land-based intercontinental missiles. The Strategic Rocket Forces today have about 360 ICBMs of four different types that can carry almost 1300 warheads, or about half of the Russian strategic arsenal. The Russian strategic fleet includes ten SLBM-carrying submarines of two types. Four of these submarines are of the older Delta III class and six are of the somewhat newer Delta IV class. The submarines that are operational, the Delta IIIs and four of the Delta IVs, carry 128 missiles with 448 nuclear warheads. Finally, Russia has 76 strategic bombers, 63 Tu-95MSs and 13 Tu-160s, that can carry up to 844 nuclear air-launched cruise missiles, although the actual number of warheads assigned to these bombers is most likely somewhat smaller. Overall, Russia is believed to have about 560 operationally deployed launchers that can carry about 2600 strategic warheads. However, most of these warheads are slated to be decommissioned in the next few years, so the treaty does not impose serious limits on the Russian force.

In order to comply with the New START Treaty requirements, the U, S. is planning to reduce the number of its ICBMs and SLBMs launchers. The current plan is to keep up to 420 Minuteman III missiles, all of which will carry a single warhead, and 240 Trident II SLBMs. This will require reducing the number of launchers on each submarine to 20 from the current 24 (the treaty allows that); two submarines with 40 launchers will be in overhaul, and these launchers will be counted as non-deployed. The number of bombers will remain the same as it is today at 60 nuclear-capable aircraft. This would mean that the U. S. will keep 760 deployed and non-deployed launchers out of the 800 allowed by the treaty. Apparently, some of these launchers will have their missiles removed, so the number of deployed launchers will be below the treaty limit of 700. Operationally deployed ICBMs and SLBMs would probably carry 1380 warheads. As for the bombers, they could still have up to 450 warheads associated with them, but the treaty accounting rules count each bomber as carrying only one warhead. This means that the U. S. would have about 1440 "accounted" warheads, although the actual number of warheads would be higher, up to 1800.

Russia has not yet made its plans public, but the composition of its future force will be determined primarily by the withdrawal of the older systems that are approaching the end of their service lives. Most of the currently deployed ICBMs will be removed from the force in the next six to eight years. As a result, Russia will have a smaller land-based ICBM force consisting of relatively new Topol-M/SS-27 missiles. Until now, these missiles have been deployed in a single-warhead configuration, but Russia has been working on a multiple-warhead version of the missile, known as RS-24. If Russia maintains the current rate of deployment of seven to ten new missiles annually, it will have about 200 ICBMs with 550 nuclear warheads by the end of the decade; about 20 of these missiles will be old SS-18 ICBMs with ten warheads each. Submarines of the older Delta III class will also be soon withdrawn from service, leaving six Delta IV submarines of which probably four will be operationally deployed. Russia is also working on a new SLBM, Bulava, which will be deployed on new Project 955 submarines. The current plan is to have as many as eight submarines with the new missile, but this is likely to change since the Bulava missile development program encountered significant technical difficulties during test flights. The program continues, but it is unlikely that Russia could deploy more than four new submarines. Thus, by the end of the decade, the sea-based component of the Russian triad would probably consist of eight submarines with 128 SLBMs and 640 warheads. The composition of the bomber force is unlikely to change significantly. Russia would probably keep all its 76 bombers, which the treaty will again count them as carrying one warhead each. Overall, this estimate shows that by the end of the decade Russia will probably have about 400 operationally deployed strategic launchers with almost 1300 treaty-accountable warheads. As it is the case with the United States, the actual number of warheads would be somewhat larger because of the bomber counting rules.

During the treaty negotiations, both Russia and the U. S. made sure that their modernization programs remain intact. At this point only Russia is actively developing and deploying new systems, the RS-24 ICBM and the Bulava SLBM and its submarine. However, the U. S. also has long-term modernization plans. When the U.S. administration submitted the new treaty to the Senate for ratification, it also made a commitment to spend about $180 billion in the next ten years to maintain the nuclear deterrence potential. About $80 billion will be spent on supporting infrastructure of the nuclear weapons production complex and $100 billion on development of a new submarine and other strategic weapon systems.

Even though the new treaty does not immediately constrain the modernization programs, in the long run it will definitely have this effect, primarily by creating the mechanism that would allow Russia and the U. S. to ensure transparency of their arsenals and to contribute to trust and confidence-building between the two states. The treaty does this by building a comprehensive verification framework that includes regular exchange of data, inspections, and access to telemetry. The New START would require each side to regularly submit data on the numbers and locations of deployed and non-deployed launchers and missiles, and it will provide an inspection mechanism to ensure accuracy of the data. The inspection arrangements of the new treaty are somewhat simpler than the ones that existed in the original START treaty, but they are in many ways more comprehensive and accurate. For example, each strategic launcher and missile will have unique identifiers that will be used to keep track of them. Also, inspectors will be able to verify the actual number of warheads deployed on missiles and certify that certain launchers, whether ICBM silos, SLBM launch tubes, or bombers, have been converted to non-nuclear use. The latter provisions are particularly important, for they could potentially be used to verify very deep cuts in the number of operationally deployed nuclear weapons. The mechanism provided by the New START treaty could be used in future agreements virtually without modifications.

Further steps toward nuclear disarmament would probably require addressing a number of issues that were left beyond the scope of the current treaty. First and foremost, as the countries move toward lower levels of deployed strategic warheads, they can no longer ignore tactical weapons and the warheads in reserve. At some point, Russia and the U. S. would be reluctant to move toward deeper reductions without a strong commitment of other nuclear weapon states to limit their nuclear forces. And finally, at some point Russia and the United States (as well as other countries) would have to find a way to reconcile nuclear reductions with the U.S. plans to deploy missile defense.

Missile defense has already proven to be one of the most contentious issues at the negotiations. Russia has strongly objected to the U.S. missile defense plans, arguing that they could potentially upset the strategic balance. It insisted on including in the treaty a statement that confirmed a link between offense and defense and, after the treaty was signed, Russia made a unilateral statement in which it asserted its right to withdraw from the treaty should the U.S. missile defense system undermine the deterrent potential of its strategic force. While this move can be seen as undermining the agreement even before it entered into force, in reality it is more likely to strengthen the U.S.-Russian dialogue and make further discussions easier. Now that Russia has had a chance to state its objections to the U.S. missile defense on record, the issue will become much less politicized. Russia and the U. S. have already been discussing cooperation in missile threat assessment and potential joint work on missile defense. This dialogue will eventually do more to resolve the tensions and misunderstandings around missile defense than probably any other process.

Regarding tactical nuclear weapons, the New START treaty opened a discussion of the issue, for without progress on strategic weapons any dialog on tactical nuclear arms was simply impossible. Now that the issue is being reevaluated, it appears that a consensus is emerging in NATO as well as in Russia about the lack of clear mission for tactical nuclear weapons. They are seen mostly as political instruments that have no useful military role. In NATO, a number of countries called on the U.S. to withdraw its nuclear weapons from Europe, a step that Russia insists should precede any discussions of its tactical nuclear arsenals. It is possible that a commitment to withdrawal will be made as part of the NATO strategic evaluation process that is currently underway and will be completed in the fall of 2010. A commitment of this kind would most certainly require Russia to make some reciprocal measures. Russia has long been reluctant to discuss its tactical nuclear arsenal, arguing that it is needed to compensate for the lack of parity between Russia and NATO in conventional forces. However, there are signs that Russia has been reevaluating this position, as its new military doctrine, released earlier this year, does not have any role for tactical nuclear weapons. This indicates that Russia may be open to a discussion of tactical arsenals. One initial step that might be discussed is a withdrawal of all tactical nuclear weapons deployed in Europe to permanent centralized secure storage facilities in the U.S. and Russia. This step should be accompanied by transparency and verification measures that could be phased in gradually to make sure that these weapons are safe and secure.

Finally, while other nuclear weapon states have not yet felt the pressure to join the U.S.-Russian bilateral disarmament process, they should seriously consider this possibility at this stage. One way for them to contribute to the nuclear disarmament process would be to accept elements of the New START transparency arrangements. For example, France, the United Kingdom and China could publish data about their strategic arsenals in the format required by the treaty. Later on they could voluntarily join the inspections regime that would allow verification of these data. This way, the smaller weapon states could make tangible contribution to the disarmament process while still maintaining their position that the U. S. and Russia should implement more dramatic reductions before other states make a legally binding commitment to reduce their arsenals.

Overall, the New START treaty demonstrates that progress toward nuclear disarmament depends crucially on cooperation between nuclear weapon states. The treaty would build a strong legal and institutional base that would ensure transparency and accountability of the process and provide a foundation for deeper reductions of nuclear weapons.

Pavel Podvig
Center for International Security and Cooperation, Stanford University
podvig@russianforces.org

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

NRC Should Perform Non-Proliferation Assessment of Laser Enrichment Technology

Francis Slakey & Linda Cohen

Uranium enrichment is a step in the process to convert uranium ore into fuel for nuclear reactors. Mined uranium ore is made up of roughly 99.2% U238 and 0.72% U235. Only the latter isotope is fissionable under bombardment by slow neutrons as in a reactor, and so in order to make reactor fuel, the U235 concentration must be increased. Enrichment services that increase the concentration are measured in separative work units, or SWUs. The number of SWUs required to produce a kilogram of reactor fuel depends on the percent of U235 in the final fuel, in the natural uranium feedstock, and in the depleted uranium stream or "tail". Numerous techniques of isotope separation have been developed for enriching uranium and their efficiency can be characterized by the number of SWUs produced per megawatt hour (SWU/MWh).

A uranium enrichment technology, SILEX (Separation of Isotopes by Laser Excitation), could significantly increase efficiency beyond existing centrifuge technologies and pose significant proliferation risks [1]. In this article we argue that an examination of the economics indicates that those risks would not be outweighed by a public benefit to the consumer in the form of lower electricity bills, as some have suggested. Consequently, under the Atomic Energy Act, the Nuclear Regulatory Commission (NRC) should carry out a non-proliferation assessment of the technology to determine whether SILEX "would (not) be inimical to the common defense and security" of the United States.

As opposed to past techniques which exploited the slight difference in mass between the two isotopes, SILEX uses a laser, tuned to a particular excitation of U235, to differentiate it from the U238. More than 20 countries have dabbled in laser enrichment over the past two decades, including South Korea and Iran, without much success. SILEX was developed by the Australian company Silex Systems, and is now being commercialized exclusively by GE Hitachi. GE Hitachi has applied for a license from the NRC to operate a full-scale commercial SILEX plant in North Carolina. Currently, the U.S. is the only country in which GE-Hitachi has applied for a license. While they have not yet made a decision whether to commercialize the technology, the license is a necessary step in their development path.

There is clear private benefit to laser enrichment: If GE-Hitachi successfully commercializes SILEX, it stands to make hundreds of millions of dollars a year. A more challenging question is whether there is a net public benefit. To evaluate the public benefit, we consider three separate issues: technical, economic, and legal.

Technical Issues

The proliferation risks of an enrichment technology can increase as the technology becomes more efficient. In general, if the technology occupies a very small space, its construction may no longer be observable through satellite surveillance. And, if it operates on very low power, it may no longer require an observable dedicated power source or have a detectable heat signature. In other words, an extremely efficient enrichment facility could be below the detection limit. The answers to just a few technical questions can begin to establish the proliferation risk of an enrichment technology:

> Can the technology be used to fabricate weapons grade fissile material?
>
> Are all the components of the technology "dual use" (i.e., do they have other non-military applications.)
>
> Is the technology undetectable in its construction and operation?

SILEX details are proprietary and undisclosed; however, based on publically available information, it is clear that the answers to some – perhaps all - of these questions are "yes" [2]. For example, the company has stated that SILEX occupies a space 75% smaller and has substantially lower energy requirements than a centrifuge facility, which would make it extremely difficult to detect [3]. Centrifuge technology is already challenging to detect, as evidenced by the recently declared facility in Qum, Iran [4] and a facility 75% smaller only increases the detection challenge.

Clearly, then, SILEX raises proliferation concerns. Indeed, it was in part this very issue that compelled the members of the APS POPA Report on Nuclear Weapons Downsizing to recommend that NRC should address non-proliferation threats in the licensing process [5]. Others have raised similar concerns [6].

Economic Issues

Could the public risks be outweighed by public economic benefits? Certainly, there is a potential for consumer savings in making enrichment more efficient. Today, ten percent of the cost of electricity from nuclear power is attributed to the cost of fuel, and of that, roughly 50% is due to enrichment costs. The Energy Information Administration estimates average fuel costs from nuclear power in the United States at 0.45 cents per kilowatt-hour [7]. In 2007, 806 million MWh of electricity was generated in the United States from nuclear power, yielding a value to enrichment services in the U.S. of approximately $1.8 billion dollars.

In 2006, a SILEX executive stated that it anticipated the technology to be anywhere from 1.6 to 16 times more efficient than first-generation gas centrifuges [1]. Since details are undisclosed, the efficiency claims are impossible to verify. But assuming a continuation of historical trends in enrichment efficiency (which follows Moore's law, as many technologies do [8]), a fair assumption is the doubling of today's best efficiency by 2020. In that case, if laser enrichment lowers enrichment costs by half and all the savings are passed on to consumers, then the average household would save approximately 66 cents per month [9].

Over time, the savings could be greater than 66 cents/household/month. For example, household savings from cheaper enrichment would rise if demand for nuclear power increases. Doubling nuclear generation in the United States by 2025 (an ambitious growth scenario for the nuclear industry) could double the value of enrichment savings to $1.32 per household a month. In addition, a change in the relative prices of enrichment services (lower) and natural uranium (higher) will increase the demand for SWUs in the production of fuel. If the price of the former halves and the price of the latter doubles, we calculate, based on a cost-optimization of formula for enrichment processes from the Massachusetts Institute of Technology [10], that demand for SWUs will increase by 40% for the same level of electricity production from nuclear power. These factors would therefore increase savings by an additional 53 cents per household a month.

The above calculation gives laser enrichment technology every possible consumer advantage, namely:

All cost savings are passed along to the consumer.

Nuclear power doubles over the next 15 years and thereby increases demand for uranium.

The process is twice as efficient as the best available technology tomorrow; and not just today. In fact, centrifuge technology may improve as well, so that the relative advantage of SILEX may be much lower than we estimate.

100% market penetration of the technology within 15 years.

All of these assumptions are far too generous to the technology, the last one particularly so. Indeed, SILEX's own documents indicate that they anticipate, at best, achieving only 25% market penetration in 15 years. In that case, conceding the other four assumptions for the sake of argument, the average household could expect a savings on their electricity bill due to this innovation to be at most 45 cents per month. That maximum savings is too meager to compel a decision to pursue laser enrichment based on public benefit to the consumer.

Legal Issues

We raised the preceding issues in an article in Nature magazine [11]. Representatives of GE-Hitachi did not challenge our conclusions; instead, they informed reporters that proliferation issues are not the business of NRC. As evidence, they point to a 2005 NRC judgment in which the NRC declined to consider proliferation issues for an enrichment facility [12]. Therefore, GE-Hitachi claims, a jurisdictional precedent was established that NRC should not consider proliferation issues in the case of SILEX.

GE-Hitachi has an overly narrow reading of the 2005 decision. Two Acts govern the jurisdiction of the NRC: the Atomic Energy Act (AEA) and the National Environmental Policy Act (NEPA). Under the AEA, the NRC must determine whether a technology "would (not) be inimical to the common defense and security" of the United States. Under NEPA, the NRC must consider the environmental impacts on the United States. The 2005 decision did not refer to any

AEA authority relating to non-proliferation issues, but instead relied exclusively on NEPA and therefore cannot serve as a comprehensive precedent. In fact, at this time, there is no precedent that would require or disallow non-proliferation assessments as part of a licensing process.

Nevertheless, the non-proliferation assessment that we propose is within the jurisdiction of the NRC based on the interpretation of the phrase "inimical to the defense and security" of the United States in the AEA. Smaller, less detectable technologies for the production of nuclear materials are potentially proliferation game-changers. Such technologies would be far more difficult to detect within the existing International Atomic Energy Agency (IAEA) Safeguards inspection regime and therefore would indeed be "inimical" to the security of the United States. The fact that SILEX is a departure from previous technologies and therefore requires close scrutiny by the NRC was acknowledged by NRC Chairman Gregory Jaczko in a recent interview:

"It's a very new technology, or a novel technology. It's not similar to the kinds of enrichment facilities we've licensed in the past. So, I certainly think there may be some things we need to take a look at and make sure we've got the right approach to ensuring that kind of protection of the technology and the material. [13]"

Additional Considerations

There have been three common responses to our analysis. First, an argument has been made that by developing laser enrichment technology in the United States, US entities can ensure that the technology is adequately safeguarded against proliferation. History does not instill confidence in this approach. Previous enrichment technologies—the calutron, gas centrifuge and advanced centrifuges—have all created proliferation risks over the past 50 years despite efforts to withhold the information. By having the NRC carry out a non-proliferation assessment to determine, among other things, whether the facility design and core technical discoveries can be secured against theft, there would at least be a possibility of reducing the risk of repeating the type of breech that led to A.Q. Kahn taking centrifuge designs from the Netherlands to Pakistan.

A second response is that "the genie is out of the bottle" and if the United States doesn't develop it, some other country—one potentially hostile to our interest—will develop it. Actually, the genie is not "out of the bottle." Historically, proliferation to rogue states doesn't occur until a technology has progressed along the learning curve to the point it has been industrially proven or has achieved production scale. The technology may be ultimately commercialized, but we believe that in this case any delay would be useful: first, in each year that the technology exists, costs exceed benefits, and second, a thorough review of risks today, together with delayed commercialization, might incentivize the manufacturers to include safeguards in the package.

A final response is that the non-proliferation assessments we propose might stymie the US nuclear industry. In fact, we believe the assessments would have the opposite effect. Careful consideration of proliferation risks is in the best interests of the expansion of nuclear power, a view that was the subject of an APS report [14].

[1] http://www.silex.com.au/public/uploads/announce/House%20of%20Reps%20Presentation%20090206.pdf

[2] http://www.fas.org/sgp/othergov/doe/lanl/docs4/silex.pdf

[3] http://www.forbes.com/global/2009/1116/outfront-nuclear-power-uranium-ge-riches-in-enrichment.html

[4] http://www.time.com/time/world/article/0,8599,1929088,00.html

[5] "Technical Steps to Support Nuclear Arsenal Downsizing," a Report by the APS Panel on Public Affairs, 2010: http://www.aps.org/link/downsizing

[6] Charles D. Ferguson, Laser Enrichment: Separation Anxiety, Bulletin of Atomic Scientists, March/April 2005; James M. Acton, "Nuclear Power, Disarmament and Technological Restraint," Survival, August/September, 2009.

[7] Electric Power Annual, EIA, 2007.

[8] Gordon E. Moore, Cramming more components onto integrated circuits, Electronics, Volume 38, Number 8, April 19, 1965.

[9] These numbers are all for 2007. That year, according to the Census Bureau, there were about 113.6 million households in the United States. Note these savings are relative to average enrichment costs in the US today, which includes the very-high cost gaseous diffusion plants. Were these plants – at $160/SWU – simply replaced by modern centrifuge plants – at a cost of $80/SWU – US households would also save. In the subsequent calculations we compare savings between laser enrichment and a modern centrifuge plant.

[10] MIT, The Future of Nuclear Power, (2003), Appendix 5.

http://web.mit.edu/nuclearpower/pdf/nuclearpower-appdx.pdf

[11] "Stop Laser Enrichment", F. Slakey & L. Cohen, Nature, vol 464, no. 7285, pp. 32-33 (4 March 2010).

[12] http://www.docstoc.com/docs/7265175/2005-RAS-COMMISSIONERS

[13] Laser Nuclear Technology Might Pose Security Risk, by Richard Harris, April 12, 2010, http://www.npr.org/templates/story/story.php?storyId=125787318

[14] "Nuclear Power and Proliferation Resistance: Securing Benefits, Limiting Risk", a report by the APS Panel on Public Affairs, 2005: http://www.aps.org/policy/reports/popa-reports/proliferation-resistance/upload/proliferation.pdf

Francis Slakey (slakeyf@georgetown.edu) is the Upjohn Lecturer on Physics and Public Policy at Georgetown University and the APS Associate Director of Public Affairs.

Linda R. Cohen (lrcohen@uci.edu) is a Professor of Economics and Law and Associate Dean of Research at the University of California, Irvine.

COMMENTARY

Invisible Nukes

Irving A. Lerch [1]

Even at an altitude of 1000 to 1200 feet, the ground beneath the aircraft moves slowly, the miniature rectangles of houses and tilled fields seem to amble, giving the illusion of remoteness. When he hurtles into the prop-blast, the world of the army paratrooper becomes a violent tumult followed by an unnatural silence until noise from below alerts him to brace for impact with the ground. The whole enterprise passes in a flash, as it must, when exposed like a dangling pendant.

The paratrooper is consumed by petty details: rigging, weapons, ammunition, what waits on the ground, where to assemble, objectives and contingencies. The primitive reflexes—fear, excitement—dominate all thought and action. Forty to fifty years ago, as one moved higher into the military chain, the accoutrements of cruelty spiraled with increasing levels of lethality. The company commander relied on rifles, machine guns, mortars and anti-tank weapons; the battalion employed heavier artillery, and then came the 105 mm howitzers and 4.2 inch mortars of the Battle Group, the 155 mm howitzers of the Division, and the 208 mm cannon of the Corps—ever escalating firepower to include short-range missiles, gunships, close-support fighter aircraft and bombers.

Through the early post-war years, this was the spectrum of weaponry from companies to battalions to battle groups, then divisions and corps. But in the late 50s and early 60s military theorists conceived of a class of tactical nuclear weapons to be placed at the disposal of ground commanders at the corps, army and theater levels (troop levels ranging from 40,000 to well over 100,000). As US strategists began to conceive ground forces for rapid deployment to distant trouble spots; they were consumed by the need to equalize the disparity in manpower and armaments when a lightly armed mobile force was confronted by greater numbers and heavier armaments.

In Europe, NATO units confronted superior numbers of heavily armored Warsaw Pact formations, and a small armamentarium of US (and later French) tactical nuclear weapons was designed and deployed to equal the odds. The complex multi-national command structure overlaying NATO forces assured that these weapons would not be placed at the discretion of any single commander.

By 1960, however, the US had organized a rapid deployment force (called the Strategic Army Corps) consisting of the XVIII Airborne Corps (made up of two parachute divisions, the 101st and 82nd) and an assortment of light mechanized units, air-carrier squadrons and naval elements. It was a given that deployment of this force would be in the face of superior enemy armies in a theater of operations not readily within reach of a WWII type logistical chain, and a whole class of low-yield nuclear weapons was developed for use by commanders. Division artillery batteries with 155 mm Howitzers could be equipped with 10 kiloton warheads as could the larger corps artillery. But most notable was the advent of a small 10-ton yield weapon called the "Davy Crockett" assigned to Airborne Division heavy mortar batteries. The Davy Crockett round weighed less than 50 pounds and was fired by a modified version of the same weapon used for anti-tank service in the infantry companies of the division.

During extensive maneuvers in the Carolinas in the summers of 1961 and 1962 (called "Swift Strike"), the Corps commander (a three-star general in command of between 40,000 and 80,000 troops) routinely incorporated atomic weapons in their mock attacks. At that time, I was a young infantry officer in the 101st, temporarily assigned as liaison with airborne corps headquarters during a Swift Strike exercise in North Carolina. My duties as liaison obliged me to attend the daily corps operations briefings and planning sessions, and I was on hand when the corps commander, a three-star general, approved a plan of attack for the following day. The scenario had the two divisions deployed in a foreign country confronting an opposing force of somewhat larger size, although we had the advantage of large naval and air support units. The objective was to break out of battlefield containment and to move onto terrain more congenial for maneuver and resupply. To do this, the operations staff recommended the use of five tactical nuclear weapons to isolate the battlefield, destroy enemy reserves and immobilize the enemy's main formations. For the referees superintending the exercise, this appeared to pose no serious consequence. The general concurred, the attack went forward, and the exercise umpires unanimously agreed that the corps had won the day.

Almost three months later, a different, more serious scenario would set the entire theoretical construct on its head.

Just after midnight sometime during the third week of October, 1962, at the onset of the Cuban Missile Crisis, a combined planning staff convened at McCoy Airbase, just outside Orlando, Florida. U2s flew in and out on routine reconnaissance missions over Cuba. An emergency military operation was being staged at the order of the President. Successive waves of paratroopers were to assault the missile storage and deployment sites on the island roughly a day in advance of the main seaborne assault. The troop air transport squadrons had been mobilized from reserve units. But this time none of the commanders mentioned tactical nuclear weapons. President Kennedy did not want to provoke nuclear war—or so he thought.

Unknown was the fact that a heavily equipped Russian division occupied the area the XVIII Corps was to assault. But even more dangerous was the fact, subsequently acknowledged by the Russian commander on the ground in Cuba (in a conference in 1990) that he had tactical nuclear weapons and was prepared to use them. There could be no doubt that the airborne troops could have been destroyed on the ground by the heavily armored and entrenched Russians and the follow-on seaborne invasion could have been vaporized.

President Kennedy would have been forced into a nuclear exchange had the invasion gone forward. The strategic game would have played out on the ground with tragic consequences. Unlike the war games in the Carolinas, friendly forces would not rely on nuclear weapons. It was not known that the opposing forces were prepared to use them.

In April, the Pentagon released the Nuclear Posture Review Report, slightly modifying US nuclear strategy as part of the ongoing process of periodic reviews of US arsenals and deployments [2]. In May, the Administration published an inventory of its strategic weaponry. And, of course, this brought condemnation from the political right for compromising US defense, with the left equally livid at the rattling of the nuclear saber.

Unfortunately the Nuclear Posture Review does not address tactical nuclear weapons despite a large and growing international inventory. Russia has an estimated arsenal of 3,000-4,000; the US 1,700-3,300; China about 400; with another 300-400 in the hands of Israel, France, India and Pakistan [3]. The future is unbounded with Iran and North Korea joining the club.

Yet if the use of even small nuclear weapons inevitably brings on incalculable escalation and the danger that loosely secured arsenals are vulnerable to terrorists, how can we afford not to confront the issue? At the time of the Cuban Missile Crisis there were dozens or perhaps hundreds of these weapons, today there are thousands spread over several continents and their whereabouts are often unknown.

For the moment the ominous shadows of nuclear weapons do not obscure the battlefield (although some planners advocated the use of tactical weapons in Vietnam—proposals universally condemned [4]). The risk, however, has been relocated from the war zones to the homeland.

But why do we hold to the fiction that tactical nuclear weapons give our military forces a secure foundation? We learned a vital lesson 46 years ago, clear even to a 23 year-old lieutenant. The existence of tactical nuclear weapons did not afford our forces any security since our enemy was willing and capable of using them, even at the risk of triggering a nuclear holocaust.

The answer is clear and urgent: an international covenant banning the development and deployment of tactical nuclear weapons. This is a better place to begin the draw-down of nuclear arsenals than the excruciating incremental reduction of useless strategic warheads.

Fifty years ago the parachute gave way to the helicopter as combat units prepared for yet another deployment, thus demonstrating that each new innovation in war carries unforeseen costs.

Irving A. Lerch
1733 Riggs Place, NW, Washington, DC 20009
(202) 462-2511, ialerch@verizon.net

[1] *Graduated West Point, 1960; Professor, NYU, retired; Former Director of International Affairs, the American Physical Society.*

[2] *http://www.defense.gov/npr/docs/2010%20Nuclear%20Posture%20Review%20Report.pdf*

[3] *http://www.nti.org/e_research/e3_10a.html*

[4] *F.J. Dyson, R. Gomer, S. Weinberg and S.C. Wright, "Tactical Nuclear Weapons in Southeast Asia," Institute for Defense Analysis, Jason Division, March 1967 (available at http://www.nautilus.org/archives/VietnamFOIA/report/dyson67.pdf)*

Photograph of a U.S.-developed M-388 Davy Crockett nuclear weapon mounted to a recoilless rifle on a tripod, shown here at the Aberdeen Proving Ground in Maryland in March 1961. It used the smallest nuclear warhead ever developed by the United States, yield 10-20 tons of TNT. Photo and caption: http://en.wikipedia.org/wiki/File:DavyCrockettBomb.jpg

NSF Ethics Education Requirements

Marshall Thomsen

The National Science Foundation's implementation of the ethics component of the America COMPETES Act (America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act, 2007) means that many in the field of physics will need to take a look at formal training in ethics and responsible conduct of research rather than relying on informal mechanisms, as has been common practice up to this point. The implementation of this legislative requirement is now underway: "Effective January 4, 2010, NSF will require that, at the time of proposal submission to NSF, a proposing institution's Authorized Organizational Representative certify that the institution has a plan to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students, and postdoctoral researchers who will be supported by NSF to conduct research." [1] While some will no doubt view this new requirement as a waste of time and a bureaucratic exercise, I believe that we should look at it as an opportunity to strengthen our community.

I do not believe that the physics community is in an ethical crisis, nor will I exploit recent incidents to argue we need to re-set our moral compass. However, survey and anecdotal evidence suggest that there is room for improvement in the ethical climate in physics [2]. Discussion throughout the physics community will help clarify the underlying issues.

Consider the Millikan Oil Drop experiment. There has been much discussion about a statement in one of Millikan's papers in which he claims to have published all of his results during a certain time span, not just a select few [3]. One can easily find, without much effort, authors who argue that Millikan was guilty of fraud, was a well-trained scientist, and everything in between [4, 5]. However, if we focus on trying Millikan in absentia, we miss the real value of this case.

The oil drop experiment is not only a landmark for physics but one that a significant portion of physics undergraduates perform, albeit with some modifications from the original. Having access to information from Millikan's original lab books and the publications that resulted provides a natural opening for discussing issues such as what is meant by data, what data we can present, what data we are obligated to present, and so forth. For instance, when one records a number in a lab notebook, does that elevate that number to the level of a piece of data? If data are the result of following a predetermined protocol for acquiring numbers, then numbers that are written in the lab book that were not generated by that protocol are not data. After the students come to recognize that data are more than just numbers, the discussion can move to when it is permissible to exclude a portion of the data from analysis or reported results. Carrying out this discussion in the context of an experiment the students themselves may have performed helps to ground it in reality. When we examine the Millikan case from this perspective, we get at the very heart of what we mean by scientific experimentation. We strengthen our profession through ethics education by deliberately engaging scientists-in-training in this discussion of the nature of science.

Evolving regulations provide another reason we owe it to our students to provide instruction on the responsible conduct of research (RCR). I would wager that many students do not appreciate the consequences of misconduct when they are working on a federally funded project. Are they aware that if they fabricate or falsify even a "small amount" of data in a professional presentation associated with a federally funded project, they cannot get off with just a slap on the wrist? Federal regulations do not permit the research advisor or department to treat the infraction in-house. Suspected misconduct must be reported to the institution's integrity officer who may then launch an inquiry and, if the evidence warrants, a full investigation. In the event the student is found guilty of misconduct, he or she will likely be debarred from working on federally sponsored research projects for several years, making completion of graduate school at any institution problematic.

Taking ethical issues seriously also strengthens our profession by cultivating public confidence in our research. This confidence in turn not only helps maintain funding for research but also makes it more likely our advice on technical issues will be taken seriously. Our responsibility as a community to provide such advice is itself an ethical issue. While we cannot be experts in all technological issues of pressing importance, each of us can develop basic familiarity with some issues. This familiarity should be as much a requirement of membership in the physics community as basic familiarity with some political issues should be an expectation for citizenship in our national community.

For instance, it is essential to the effective use of public resources that there be a common understanding regarding possible harmful effects of 60 Hz radiation; there is no known physical mechanism to suggest that the normal exposure we receive from this radiation on a daily basis could impact our health. Our colleagues in the life sciences would add that, with the possible exception of childhood leukemia where there may be a weak link, the overwhelming epidemiological evidence indicates that this radiation does not pose measurable harm [6]. Thus, our society should focus its prevention resources on other, more pressing problems. Although RCR is not generally taken to include these science and society issues, helping our students appreciate them is essential to the health of both our profession and our society, and is part of a broader training in professional ethics.

What would RCR education for a physicist look like? Many universities are relying on modules developed by the Collaborative Institutional Training Initiative (citiprogram.org). These modules provide a general discussion of key areas in RCR education. The original modules were developed with the life sciences in mind, but there have been some modifications made to produce a parallel set directed at the physical sciences. However, the life science influence is still quite apparent in this set. For instance, the module on authorship and publication refers to standards associated with biomedical journals only. It is important that generic material on scientific ethics be supplemented with additional material of direct relevance to physicists.

RCR education for a physicist is not complete without covering relevant standards within our own community, specifically, the APS Guidelines for Professional Conduct and related statements. An introduction to publication standards developed by key journals such as Physical Review would also be appropriate. There are case studies with discussion posted on the APS website. Finally, there are numerous articles in publications within our community (such as this newsletter and Physics Today) that are of direct relevance to the responsible conduct of physics research [7].

There needs to be some form of assessment for an educational program to be complete. Assessment in the CITI modules is limited to multiple choice questions, and those are not always very closely tied to the learning objectives stated at the outset of the module. A more relevant assessment would have the student demonstrate the ability to apply physics community standards to a less than trivial case. The form of the assessment could be an essay, participation in a discussion, or presentation of a seminar. This need not be a burdensome task: a ten minute discussion with a student is likely to reveal a lot more about them than their performance on a handful of multiple choice questions.

As we work with NSF and our universities to implement the directives of America COMPETES, I hope we take this opportunity to begin meaningful discussion of ethical issues in physics. We can do so not out of a sense that our community is in desperate need of reformation and that we have a lot to be embarrassed about, but rather out of a conviction that we have the opportunity to strengthen both our community and society at large. We should not settle for generic approaches designed to accommodate all forms of NSF-sponsored research within our university communities. Instead, we should be assertive in modifying the plans to accommodate the needs and interests of our own students so that RCR education is not just a bureaucratic requirement but a true educational experience.

[1] Federal Register, Volume 74, Number 160 Notices pp. 42126-42128 (August 20, 2009).

[2] Kate Kirby and Frances A. Houle, "Ethics and the Welfare of the Physics Profession." Physics Today, Volume 57 Issue 11 pp. 42-46 (November 2004). See also letters to the editor in Physics Today, Volume 58 Issue 7, pp. 12-17 (July 2005).

[3] R. A. Millikan. "On The Elementary Electrical Charge and the Avogadro Constant," Physical Review, 2(2), 109-143 (1913).

[4] William Broad and Nicholas Wade. Betrayers of the Truth (New York: Simon and Schuster, 1983).

[5] David Goodstein. "In Defense of Robert Andrews Millikan." Engineering and Science, Volume 63 Issue 4 pp. 30-38 (2000).

[6] Electric and Magnetic Fields Associated With the Use of Electric Power. National Institute of Environmental Health Sciences (June 2002).

[7] For an annotated bibliography, see http://www.physics.emich.edu/mthomsen/ethics/eiphome.htm.

Marshall Thomsen
Department of Physics and Astronomy, Eastern Michigan University
jthomsen@emich.edu, (734) 487-8794

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.

REVIEWS

Storms of My Grandchildren: The truth about the coming climate catastrophe and our last chance to save humanity

By James Hansen (Bloombury USA, New York, 2009), ISBN 978-1-60819-200-7, 304 pages, hardcover $25

James Hansen is concerned about the world that his grandchildren: Sophie, age nine and Conner, age four, will inherit. He's written a blockbuster that will be widely discussed. During the past two decades there has been a deluge of books, most of them good, about global warming. This is the most important of the lot.

Hansen is an accomplished scientist. He came to national attention in the 1980s when he testified before Congress and made a series of accurate predictions regarding the severity of global warming. He directs NASA's Goddard Institute for Space Studies, and is adjunct professor at Columbia University's Department of Earth and Environmental Sciences. Congress frequently calls him to testify on climate issues. He has authored and co-authored an impressive number and variety of scholarly papers centering around climate change, papers that are unusual for their depth of analysis and breadth of focus.

The book is primarily about the science of global warming. It argues that present policies will lead to a climate catastrophe; in particular, the present atmospheric carbon dioxide (CO_2—the primary cause of global warming) concentration is already too high and needs to be reduced from its present 390 parts per million (ppm) to around 350 ppm. More briefly, toward the end of the book, Hansen offers his remedies: a moratorium on new coal plants until their CO_2 can be captured and stored, and a plan to tax CO_2 emissions and fully rebate the tax revenues to citizens.

Hansen is unusual among climate scientists in drawing conclusions predominantly from empirical data rather than from computer simulations. Computer models can be valuable, but it's always difficult to know whether all relevant variables are included in the model, and some variables (such as clouds) are nearly impossible to compute. Empirical data come from mother nature, she includes all the variables, and she can do all the calculations.

For example, one of Hansen's figures graphs 65 million years of temperature history. The graph draws on evidence found in deep-ocean sediment "cores" (a long vertical pipe full of sediment inserted into the ocean bottom and then pulled up) and reported in 2001 by other scientists. Such a core contains evidence of the temperature and date of deposit at each position along the core.

Hansen draws several lessons from this graph and related evidence. One is that a long-term 9-degree (Fahrenheit) warming, during 59 to 50 million years ago (Mya), was caused by natural releases of CO_2 into the atmosphere. Another lesson comes from the "Paleocene-Eocene thermal maximum" (PETM), a sudden 8-degree temperature spike 55 Mya. Hansen convincingly locates the cause. Rising ocean temperatures caused deposits of "methane ice" (a frozen mix of methane and water that gathers on the ocean floor) to melt and release large amounts of methane (a potent greenhouse gas) into the water, and the methane bubbled up to the atmosphere. Once methane release began it necessarily continued until essentially all the methane ice was melted, because the initial release warmed the atmosphere further, which caused further releases, and so forth in a vicious circle.

Hansen points out another lesson: The planet has generally cooled during the last 50 My, and new methane ices have had ample opportunity to spread over the ocean floor. CO_2 and temperatures are again increasing. We're putting ourselves in danger of another PETM-like event. But unlike 55 Mya, Greenland and West Antarctica today hold huge ice sheets that would eventually melt under a massive methane release, causing catastrophic ocean rise.

Hansen's long-term perspective demonstrates the enormous rate of change that humans are imposing on the natural world. The warming 59 to 50 Mya was caused by an increase in atmospheric CO_2 concentrations that averaged only one ppm every 10,000 years. By comparison, today's CO2 concentrations have increased by over 100 ppm in just two centuries! Wherever this is taking us, it's taking us mighty fast.

Today's CO_2 concentration is nearly 390 ppm, 40 percent higher than it's been during at least the past 800,000 years. This CO_2 spike occurred just since the beginning of the industrial age around 1800. As Hansen explains, this 390 ppm level is not sustainable: Marine species are suffering multiple stresses from warmer oceans; tropical regions are expanding, bringing spreading drought, deserts, and fires; the Greenland and West Antarctic ice sheets are losing mass at unacceptable rates; mountain glaciers are disappearing; and Arctic summer sea ice will soon vanish. It's "difficult to imagine how the Greenland ice sheet could survive if Arctic sea ice is lost entirely in the warm season."

Policy makers have talked for years about stabilizing the climate at 450 ppm, but in light of the trends, Hansen asserts that even 390 ppm is too high. What's the maximum safe level? Hansen is a proficient calculator of such problems. He calculates that a reduction from 390 to 350 ppm will restore planetary energy balance and stabilize the dangerous trends noted above. This won't happen overnight, and we'll be living dangerously until we get back to 350 ppm.

Hansen doesn't shrink from entering the policy debate. He advocates a moratorium on new coal-fired power plants until coal's CO_2 emissions can be captured and stored underground. This is essential and needs to begin today, but corporate interests prevent it.

Hansen opposes the much-discussed cap-and-trade solution because it's complex and thus subject to corporate abuse. He instead supports a gradually increasing direct tax on carbon in order to reduce carbon's use, with the tax income rebated back to the public. The total amount collected each month would be divided equally among all legal adult residents, with half shares for children. For example, when the tax reaches \$115 per ton of CO_2, every family of four would receive a rebate of \$8000 to \$9000 per year. All economists seem to agree that tax-and-rebate is the simplest, cheapest, and most effective plan. Nevertheless, I disagree with Hansen's opposition to cap-and-trade, because it's the only plan that's been widely accepted, and most Americans will not support a carbon tax. Environmentalists should support both cap-and-trade and tax-and-rebate.

Check out Hansen's web site at www.columbia.edu/~jeh1/. Under "recent presentations," see his 10 December 2009 video interview on David Letterman's Late Night show. If you don't see this listed, try clicking on "older presentations."

Whether or not you agree with Hansen, do read his book.

Art Hobson
Dept of Physics, Univ. of Arkansas, Fayetteville
ahobson@uark.edu

Sustainable Energy -- without the hot air

By David JC MacKay (UIT Cambridge Ltd, Cambridge, England, 2009) ISBN 978-0-9544529-3-3 (paperback) ISBN 978-1-906860-01-1 (hardback), 368pp

"In a climate where people don't understand the numbers, newspapers, campaigners, companies, and politicians can get away with murder. We need the numbers to be comprehensible, comparable, and memorable. With numbers in place we are better placed to answer the difficult questions concerning issues." So declares David MacKay, a Fellow of the Royal Society and a professor in the Department of Physics at the University of Cambridge, where he has learned that lesson well. That statement is the underlying theme in this book, a theme that differentiates it from the many other recent books on global warming. With meaningful numbers and facts we are liberated from "a flood of crazy innumerate codswallop." At the moment, where numbers are used they are frequently chosen to impress, to score points in arguments rather than to inform. The aim of this book is to help the reader figure out the numbers and do the arithmetic so that he or she can evaluate policies, and see which proposals add up. This book is about physical limits and not about economics and ethics which, while forming a part of the policy-making process, are more appropriately described by specialists in these fields.

With this introduction, it is no surprise that Part 1 of the book's four main parts is titled "Numbers not adjectives;" it has 17 subsections, dealing with the energy associated with cars, wind, solar etc. Eventually the quantitative information we learn can be applied to arrive at a quantitative estimate of the maximum energy that a country can use and still be consistent with a maximum 2.0°C rise in temperature in the year 2050. Knowing the maximum allowable energy, one can then consider what combination of energy sources can be used.

Numbers imply units. Basically MacKay has chosen to use the MKS system, with the kilowatt (kW) as the unit of power, and the kilowatt-hour (kWh) as the unit for all forms of energy. Derived units include the kilowatt hour per day (kWh/d), and the kilowatt hour per day per person (kWh/dp). These latter units enable easy comparisons between the various fuels and their use in various countries or regions. Such comparisons are vital to planning and policy making. Where do the basic numbers come from? Some come from good measurements, but some must be reasonable assumptions. This produces uncertainties in the final values, and consequently sometimes these may be factors of 2 or more. This process is similar to back of the envelope calculations encountered in scientific circles, and is subject to change as better information becomes available.

The book is intended to be accessible to anyone who can add, multiply and divide. MacKay adds that "it is especially aimed at our dear elected and unelected representatives, the Members of Parliament." More technical details are in Parts 3 and 4. Any reader with high school qualifications in math, physics, or chemistry should enjoy these chapters. For more non-intrusive reading, many details are put into footnotes at the end of each chapter. A wealth of information and useful data is stored in this book. These along with an extensive bibliography make the book a valuable reference; in fact many will find Part 4 the most valuable aspect of the book.

One of the questions tackled in Part 1 is "Can we live on renewables?" Here MacKay does a detailed study of the situation in the United Kingdom (UK). This may be somewhat frustrating to those living elsewhere, but later in the book he briefly indicates how to extend his methods to Europe, North America and finally to the world. He concludes that for the UK it would be very difficult for non-nuclear renewables alone to provide sufficient energy. The remaining renewables are very diffuse and therefore large country-sized areas are needed to make a substantial difference. The wind farms in the UK, for example, would need to be the area of Wales, which conflicts with cropland and forestry requirements. The British public, like the public in the world in general, must learn to reject some of the controversial NIMBY arguments. Europe also could not live on non-nuclear renewables; it would be necessary to expand nuclear energy and/or import energy in the form of solar power from other people's deserts. Similarly he concludes that without solar or nuclear power North America would have insufficient energy, but it is different from Europe in that the solar power could come from its own deserts and would not have to be imported. It is a considerable extrapolation to treat the world, but the conclusion is similar. The non-solar renewables are huge, but not huge enough. More forms of solar power or nuclear power are needed.

The penultimate chapter of Part 2 is titled "The last thing we should talk about." If all else fails the last line of defense may be capturing CO_2 from thin air, a subject rarely mentioned among the possibilities. Here, it's enough to note that various methods have been suggested and should be pursued along with all the other possibilities suggested in this book.

Part 2, titled "Making a Difference," accepts the idea that the world's energy problems cannot be solved by renewables alone. MacKay replaces the mantra "Little changes can make a big difference" with "If everyone does a little, we'll only achieve a little" and "Every big helps." Major changes are essential. He considers two general lanes of inquiry: reducing demand (better transport, smarter heating), and increasing supply (efficient electricity use, sustainable fossil fuels, living on other countries' renewables). I appreciated his chapter titled "Nuclear?" in this latter category. He leaves it to the reader to answer the question, but at the same time provides estimates that knock down many of the anti-nuclear arguments.

Taking all this into account, he suggests five energy plans for the UK, each aimed to appeal to a particular class of people: pro-nuclear, pro-wind, pro-NIMBY, pro-diversity, and pro-economics. No one will be completely satisfied, but the exercise illustrates that there is a large range of possibilities.

The wealth of information in this book is immense. For example, in Part 3 there are details about the physics of wind power, a simple description of how a plane flies, energy-efficient buildings, and much more. This diversity of ideas and information, along with the achievement of the author's quantitative goals, make this a very welcome book.

Peter Schroeder
Emeritus Professor of Physics, Michigan State University
Schroeder26@gmail.com

Earth: The Sequel, The Race to Reinvent Energy and Stop Global Warming

By Fred Krupp (President of Environmental Defense Fund) and Miriam Horn, W. W. Norton & Company, New York (2009). ISBN-13 978-0393334197, $15.95 (paperback).

This book announces on page 1, "A revolution is on the horizon: a wholesale transformation of the world economy and the way people live. This revolution will depend on industrial technology …and will almost certainly create the great fortunes of the twenty-first century. …This book is about the kinds of inventors who will stabilize our climate, generate enormous economic growth, and save the planet. It is also about the near certainty that unless the U.S. acts as a nation to let these innovators compete fairly in the world's biggest business, they will fail to avert the crisis in time."

Of course, a discussion of energy and the environment could instead start with an examination of the size and reliability of estimates of the world oil reserves, the current and predicted energy needs of the world, and efficiencies of energy transport. This approach is likely to be closer to the way we as physicists examine and catalog the world. However, the decision-making powers in the US, and other developed nations, are tied almost exclusively to economic and business logic, or more cynically to purely political concerns. A policy book, to have political impact, needs to be directed in this way.

That said, the science implicit in "Earth: The Sequel" is essentially sound, with the possible exception of a few of the "world of possibilities" long-shot options near the end of the book--options judged to have a lower likelihood of success. The economics are more debatable; carbon credits make a brief (positive) appearance and carbon taxes are casually dismissed as "not enlist[ing] the full range of human potential." Contrast that with the comment of James Hansen (NASA's chief climate scientist) on carbon credits: "This is analogous to the indulgences that the Catholic Church sold in the Middle Ages. The bishops collected lots of money and the sinners got redemption." But that's a longer discussion for another book.

The technologies addressed in this book include solar photovoltaic, solar thermal, biofuels, ocean energy extraction, geothermal, "clean" coal, so called "solutions for today" (e.g., stopping deforestation, increasing energy efficiency), and the more speculative "world of possibilities" (including fusion, high altitude power kites, undoing the global environmental damage via geoengineering with "proper caution," and nuclear fission). The general approach is to discuss the current state of the art technology in each area and then note a small start-up with a plan to push beyond the current limits and make the technology more efficient or cost-effective. Some of these ventures will surely fail, Krupp notes, but not all of them, and there are a lot of hopeful enterprises on tap here. Optimism pervades the two hundred and seventy pages of text. It is an optimism that science and technology will solve, or rather is currently solving, the horrible mess of global warming.

That sort of scientific optimism is rare in discussions of the current state of the environment, although another book with a similar optimistic and business-oriented analysis of energy technology is Ayres & Ayres, "Crossing the Energy Divide." I'd wholeheartedly recommend "Earth: The Sequel" to the interested physicist who is willing to push through the business and financial envelope surrounding the technical topics presented by Fred Krupp. You may disagree in places, but there's a lot of valuable insight here into the firms pushing for the energy solutions of the twenty-first century.

Michael DuVernois
University of Hawaii
duvernois@phys.hawaii.edu

More: Population, Nature and What Women Want

By Robert Engelman (Island Press, 2008), $24.95, 242 pages plus notes, bibliography and index. ISBN 978-1597260190

This well written book is extensively researched and has a sense of humor. Its author is vice president for programs at the Worldwatch Institute and was vice president for research at Population Action International. The book's ten chapters have such interesting titles as "The Grandmother of Invention," "Punishing Eve," and "Zen and the Art of Population Maintenance." The idea for the book came from population activist Sharon Camp, who suggested that if the world's women could determine for themselves when and when not to have children, population problems would resolve themselves.

Noting in the introduction that a net 215,000 people are added to the planet every day, Engleman asks some important questions: Why do people have such a poor notion of population statistics? Why do the media track economic growth but not population? Why do environmentalists ignore demography? Why is there a widespread notion that the real population crisis is not growth but decline? The next few pages discuss the global warming and human suffering caused by Earth's billowing population. The introduction concludes with the book's theme: "It's astounding how many words have flowed in the population debate without much consideration of the lives of those who bear and raise children."

The book describes strategies for successful procreation and for the evolution of marriage. After describing the prehistory of human migration and the fate of the Neanderthals, Engelman postulates that humans have been able to relate to each other in large groups due to the evolution of language.

The environmental impact of increasing population is an important theme. Intensive farming, described as a mixed blessing, is one important factor. According to Smithsonian Institute forensics expert Douglas Ubelaker, "Infant mortality, tooth decay, anemia, infectious disease all worsened with agriculture and sedentism." And according to noted author and geologist Jared Diamond, maximum population means maximum environmental impact. As an example, Engelman describes the ongoing environmental disaster in Madagascar.

Regarding women's attempts at population control through contraception, Engelman writes "Although intensely personal, collectively these childbearing decisions shape the dynamics and structures of human populations--assuming the intentions are realized." This leads to a conclusion of the effect of female equality on the outcomes of ancient societies. "In some of the settled societies…there is evidence of relatively high status for women in general. …Yet this relative gender equality may have cost these societies the population growth they eventually needed to defend themselves from the more demographically dynamic pastoral invaders."

In a chapter titled "Axial Age," Engleman indicates that humanity shifted on its axis by subjugating women's role in society. The chapter deals in large part with contraception. Engelman presents evidence that women who assumed the role of midwife began to be identified and prosecuted as witches, and discusses the spread of sexually transmitted diseases, and migration of Europeans into the New World.

The book includes the interesting story of social reformer Margaret Sanger, as well as the population control policies of the United States and other countries. Another interesting story explains that Texas Congressman George H. W. Bush was nicknamed "Congressman Rubbers" for his avid support of population control, yet when he became Ronald Reagan's running mate in 1980 Bush announced that there would be no more talk about population and family planning.

Engelman's central theme is, "The best way to 'control' population is to give up control, in fact to give control away to those who can best decide for themselves when to bear a child." In the final chapter, "The clearest principle to guide us is that those who bear children should be the ones…to decide when to do so. …Wanting not more people, but more for all people, we might find ourselves at home again, with more nature than we thought possible, in an Eden we can keep."

More is an encouraging book that I recommend to everyone with an interest in the long term future of humanity and our world.

Frank Lock
Retired, formerly at Lemon Bay High School
fasterlock@att.net