

PHYSICS & SOCIETY

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EDITOR'S COMMENTS

I must apologize to our readers for the unusually short size of this issue — we have received very little appropriate publishable material. We have always hoped to publish papers presented at our Forum's sessions at APS meetings (as well as other pertinent material) to enable our readers who missed the meeting to participate in the intellectual life of our Forum. I'm told that our recent sessions have been very successful — unfortunately, our session organizers have not been able to secure papers from these recent meetings for the Forum's

journal. I can only hope for more cooperative Forum presenters in the future as well as many more submissions from other sources. A forum implies participation — please do so!

A major concern of the Forum on Physics and Society is the history of the human aspects of our science. It is important in physics teaching, the production of new physics, and developing the interaction between physics and society. Two

Continued on page 16

IN THIS ISSUE

EDITOR'S COMMENTS

ARTICLES

- 2 Successful High School Teaching of Modern Physics:
Overcoming Inherent Difficulties, *Max George Doppke*

COMMENTARY

- 4 Getting History Right is an Important Matter, *Jeffery Marke*
5 When Someone Else's Office Becomes Yours, *Alex Starace*
6 How to Solve Global Warming, *Art Hobson*

NEWS

- 7 Concerns Voiced Over Future of Space Science Programs,
Audrey T. Leath
9 OSTP Director John Marburger on Science Policy and Budget
Issues, *Richard M. Jones*
11 Federal, State Recommendations on STEM Education, *Audrey
T. Leath*

REVIEWS

- 12 Nuclear Shadowboxing Vol. 2: Legacies and Challenges, by
Alexander DeVolpi, Vladimir E. Minkov, Vadim E. Simonenko
and George S. Stanford, *Reviewed by Peter B. Lerner*
13 Bomb Scare: The History and Future of Nuclear Weapons, by
Joseph Cirincione, *Reviewed by Cameron Reed*
14 Physics of Societal Issues: Calculations on National Security,
Environment, and Energy, by David Hafemeister, *Reviewed by
Cameron Reed*
16 The Grid: A Journey Through the Heart of our Electrified World
by Phillip F. Schewe, *Reviewed by Joe Levinger*

IN THE APRIL WEB ISSUE

NEWS OF THE FORUM

- Election Results
Obituary – Mike Caspar
Statement from Incoming Chair
Student Fellowships in Physics and Society

ARTICLES

- How Much Warhead Reliability Is Enough for a Comprehensive
Nuclear Test Ban Treaty? *David Hafemeister*

COMMENTARY

- If Only Rainwater was Beer, *Lowell Grisham*
Reflections on Being a Second Wife, *Carol Oen*

NEWS

- Age Associated Blindness – Self Induced

REVIEWS

- The Long Emergency: Surviving the End of Oil, Climate Change,
and Other Converging Catastrophes of the Twenty-first Century,
by James Howard Kunstler, *Reviewed by John L. Roeder*
Big Coal: The Dirty Secret Behind America's Energy Future, by Jeff
Goodell *Reviewed by Louis Schwartzkopf*
Living with the Genie: Essays on Technology and the Quest for
Human Mastery, edited by Alan Lightman, Daniel Sarewitz,
Christina Desser *Reviewed by Matthew Sharp*

ARTICLES

Successful High School Teaching of Modern Physics: Overcoming Inherent Difficulties

Max George Doppke

Introduction

During the few years that I have been teaching high school physics, complexities in the learning processes of students have surfaced in specific aggregate patterns that hindered their ability to participate and benefit fully from a study of modern physics. Through careful analysis and documentation, I have been able to categorize these patterns into three basic areas — pragmatic, conceptual, and philosophical. The pragmatic area simply deals with making sure the individual students are a good fit for your class. Getting them to think, question, and visualize in a way that increases overall understanding lies with the conceptual framework. The philosophical area concerns the overall spirit of the student, and hence, their motivational core. The educator, by nature of his or her position, is connected to all of the students through each of these areas. If the connection is poor, limited, or unidirectional, the system will break down. If, on the other hand, it is maintained and developed guardedly, maximizing each link and sacrificing none, a cohesive, balanced and dynamic class will result.

In modern physics we find a subject that is sufficiently esoteric, provocative, conflicted, complicated, unintuitive and emotional, so as to present an almost unique situation for high school students. The likelihood of difficulties arising concurrently from the abovementioned areas, and in varying degrees, increases dramatically. The results can be devastating - on one had, a person completely turned off to science. On the other, the development of ‘science schizophrenia’ – whereby an individual goes through the motions to pass the class, but the science stops there. In either case, society is the loser, and recovery can be slow and painful. Fortunately, there are ways of addressing these difficulties in order to realize a more positive outcome.

The Pragmatic Area

Pragmatic area concerns are easy to spot. Some students are just ‘out of sync’ with the rest of the class. Delving deeper, we find a decided lack of mathematical skills and/or prior knowledge. Functionally, this shows up as an inability to do the required computations, or a lack of skills in analyzing data and translating it into functional equations.

Since the point of a physics class is to do physics, remediation should not occupy more than a cursory role at any time. To this end, the instructor must be pro-active in limiting the class to those who can succeed. This is not eas-

ily accomplished, and is often at odds with counselors who view your class as a ‘dump’ for previous failures, and with administrators who believe everyone should have a chance. If prerequisites cannot be established, it is incumbent, via written communication, that counselors, parents, and students be informed, and in acknowledgement of, the complete scope of the class. If properly done, most uncommitted and otherwise lacking students will choose an alternate class.

Many students are simply flummoxed by word or data driven problems, even when the simplest equations are involved. Time and time again, students will either submit work that does not vaguely relate to the problem, or turn in a blank paper. Preventative measures can be implemented the first day of class in the form of a carefully worded syllabus highlighting: a) frequent, graded home work. b) weekly quizzes. c) cooperative groups focused on problem solving. d) participatory review sessions.

To complement this, the instructor will make every effort to solve a variety of text-based problems in class. Students can then be instructed to work in competitive groups on problem sets representative of those they will be required to solve on a quiz or exam. This will provide immediate feedback, alert the instructor as to potential problem areas, and provide a lively and cooperative atmosphere. Reward systems can be agreed upon by students and teachers in advance.

The Conceptual Area

Conceptual difficulties arise when a student cannot find a way to mentally compartmentalize a new idea by relating it to something already cognitively labeled and filed. Not surprisingly, this is a common side effect of studying modern physics. Relativity, uncertainty, probability, wave-particle duality, quantization, virtual particles, anti-matter, and the like, all have their share of bugaboos that play havoc with the sanity of secondary school students. The remedy herein lies with the marriage of imagination and technology, natural comrades of today’s students.

To lighten the load and ease the way, instructors should make ‘gedanken’, or thought, experiments a commonplace group activity for discourse and enlightenment – the goal being to increase the general comfort level among the students as their ability to conceptualize grows. Within this framework, cross-curriculum, multi-cultural, and historical formats should be employed to add variety and connect with the most people.

The physics of Star Trek, archeological radioactive dating, musical instruments, saying ‘relativity’ in Spanish or Chinese are but a few examples of what can be used. If coupled with technology, results can be stupendous.

Frequently overlooked, educational media offers substance with variety to aid students in concept acquisition. Programs, such as those presented by Standard Deviants and Ztek Physics Classics, provide for an interactive format with immediate feedback and reinforcing quizzes. Entire experiments are performed and compiled on DVD format with multiple applications.

Also encouraging is the trend, pioneered by CPO Science, to deliver educational units rather than stand alone textbooks and peripherals. These units are based upon core lab activities to which equipment is provided. The lessons, text, assessments, assignments, and peripherals all revolve around and relate to the labs. And don’t forget the fieldtrips! A 300GW nuclear power plant makes quite a real-world impression.

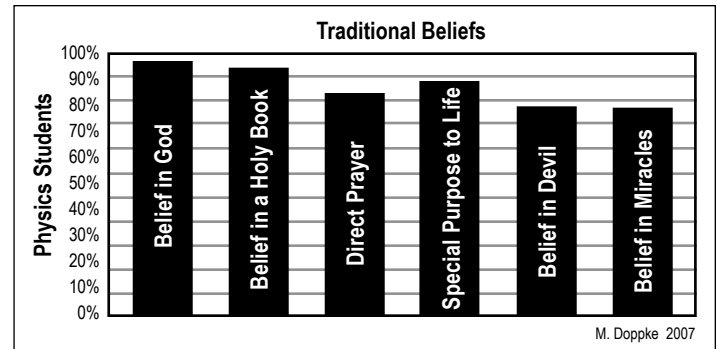
Philosophical Area

Of all issues, the ones of a philosophical nature are by far the most complex primarily due to their varied nature and intangible qualities. Additionally, the instructor, coming with his or her own baggage, is assigned a role closer to interactive participant than of facilitator and teacher. The two most problematic issues of this area confronting education today are the belief systems of the students and the compartmentalization of science learning.

A belief system is a philosophical and/or religious framework through which an individual relates his or her existence to his or her experiences. I became aware that a potential problem exists through common dialog with students, where many of my open-ended questions were answered from this base. For example, when a group of physics students was asked why they thought most life on earth was sensitive (as in perceptible) only to a narrow range of electromagnetic radiation. The most common answer was that God had created life to best survive on this planet. If my response had something to do with leaving religion out of science, I lost more than half the class. When my response was positive or receptive, the interest level reflected it and remained high. Even a simple “AND... SO.....” or “BECAUSE.....” on my part indicated that I wanted more information, yet was not dismissing the student’s comment as irrelevant. Could it be that teachers are unwittingly placing science in an adversarial role? Just one more reason for people to distrust science, and something I wanted to avoid.

Curious to discover what my classes thought and how they felt about certain issues, I devised a simple, anonymous questionnaire in which students responded to statements about

personal beliefs, attitudes, and orientations that might relate somehow to the study of science. The sample size consisted of fifty current high school physics students. They were given a set of statements to which they had three choices: agree, disagree, and not sure. The results were truly enlightening:

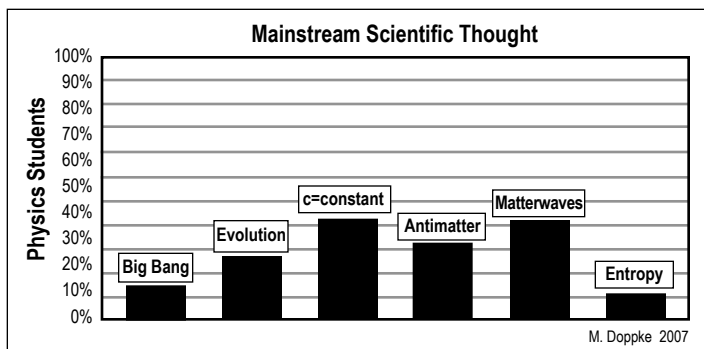


It is clear that traditional beliefs are held by the vast majority of students in my classes. To add to this, students are more vocal and less ashamed about having these belief systems, often bringing them into conflict with science teachers who trivialize and marginalize them. Therein lies the real danger.

When a fundamentalist says that God created the world in six days, say that God also made time relative, and go on from there. This may not be politically correct, but to me, as a teacher, it makes perfect sense. The goal is to have students learn modern physics. If by making the weirdness and strangeness miraculous, or by giving humanity a special purpose, the subject stirs some feelings of connectedness in any student, I’m all for it. Discussions that can center on multiple universes and vibrating strings in eleven dimensions can easily entertain anthropism, deism, creationism, or any other ‘ism’ for that matter – not as science but as to why we need science. Science is a tool for the acquisition of knowledge. It is not a competitor of religion. Asking our youth to choose between them is a losing proposition.

A direct consequence of a teaching style that refuses to validate the student’s belief system is the compartmentalization of science learning. It is a case of “When in Rome, do as the Romans do.” In this scenario, students come to science class, go through the motions, do the labs, take the tests, pass the tests, pass the class, and move on, knowing all along that they aren’t really Romans and actually despising everything the Romans stand for! Why? Because the Romans either refuse to accept them for whom they are and/or fail in showing them any value in being Roman. Of course, Rome in this case is the scientific community, and science teachers are the ambassadors.

Curious about my own students, I analyzed their responses as they related to some commonly held, mainstream scientific thoughts or theories. Less than twenty percent of my students actually believe that there was a Big Bang, or that the universe



is about fifteen billion years old. Less than half feel that anti-matter exists, or that light has wave and particle properties. Yet these same students will repeatedly come to class and pass exams on subjects such as beta decay and electromagnetic fields. Why, they even solve their problems on solar calculators!

What this indicates is a major disconnect in science education and the scientific community. These young people walk through classes like zombies — dead to the fact that what they are learning actually has meaning; actually has value.

The less value something has, the less people want it. The gap gets wider and wider, until eventually you establish scientific elite, separated by a gulf of knowledge and experience, and speaking a language no one can understand.

To ameliorate this situation, bridges must be built to link students, educators, scientists, academicians and industry — bridges that link the mind, the heart and the soul of today's youth — bridges that connect with the future, for all of us.

Conclusion

A successful teacher is one who can create a situation whereby the most students can have the best experience learning with excitement and challenge at minimal stress to the psyche. Modern physics carries with it its own unique set of difficulties. These are by no means insurmountable. The insights and suggestions I have provided are a way to address the difficulties, and bring teachers closer to success.

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COMMENTARY

Getting History Right is an Important Matter

Jeffery Marque

“Getting history right is an important matter.” Thus begins a paper by Dr. Arjun N. Saxena, entitled “Monolithic Concept and the Inventions of Integrated Circuits by Kilby and Noyce” and presented by him on May 24 at the Nano Science and Technology Institute Annual Conference in Santa Clara, California. Saxena himself was a primary participant in the development of integrated circuits (ICs), and his paper goes into great detail about matters about which many people (myself included) had not gotten the “history right.”

I met Dr. Saxena at the 88th birthday celebration for Professor Wolfgang Panofsky at Stanford Linear Accelerator Center (SLAC) in April of this year. The conversation between us drifted toward the subject of historical accuracy, and he asked me who I thought had invented the integrated circuit. When I answered “The usual understanding is that Jack Kilby invented the integrated circuit,” he told me about his upcoming talk about the subject and invited me to attend.

Jack Kilby won the Nobel Prize in the year 2000 for his role in the invention of the integrated circuit, and many people assume that the ICs now in use are due to Kilby's invention. At his presentation, however, Saxena presented extensive historical evidence pointing to major roles by other inventors. I would

say that Saxena's main point is that the monolithic IC was not invented by Kilby, but rather by Robert Noyce. Instead, Kilby invented a hybrid IC, a type that is not used commercially. Saxena emphasized the distinction between the monolithic and the hybrid IC, referring in his paper to the former as “...the only kind sold from the inception in the IC industry...”

Quotations from his paper give very clear voice to the points that he wished to emphasize:

“The issues in the inventions of ICs by Kilby, Noyce and the others are intricately entwined technically, chronologically, and legally patent wise....the key concepts for the monolithic IC were first documented by Noyce, even though the reduction to practice of his invention was done by others, and it depended crucially on Hoerni's and Lehocvec's inventions.”

“Kilby missed the key concepts of monolithic interconnects and planar technology necessary to fabricate monolithic-IC. The reduction to practice was done by Kilby [himself] using Ge [germanium] mesa technology and wire bonded interconnects dangling above the chip which are not used in monolithic-ICs. Kilby was awarded the Nobel Prize in 2000, and he is generally regarded as the inventor of ICs, implying

monolithic ICs, which is not pedantically accurate.”

One of the more intriguing ideas presented by Saxena concerns the filing date of one of Kilby’s patents. Kilby claimed a filing date of February 6, 1959. However, when Saxena dealt with the patent office to obtain copies of Kilby’s application, he received two contradictory responses: One response indicated a filing date of May 6, 1959, and the other response said, “The product or service you requested cannot be fulfilled because the application ... does not have an official filing date.” Saxena wrote in his paper, “The above seemingly contradictory responses from the USPTO cannot be explained...one fact is clear from the above responses: the

official filing date of Kilby’s [application]...was not February 6, 1959, as claimed by Kilby....Either it was May 06, 1959...or it did not have an official filing date at all...”

I found Dr. Saxena’s paper fascinating because it gives a detailed example, of great historical importance, of how ideas can be “intricately entwined”. In the case of important ideas, this can lead to distortions of history, both intentional and unintentional. The entire abstract of his paper can be viewed now at <http://www.nsti.org/Nanotech2007/WCM2007/#Saxena>.

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When Someone Else’s Office Becomes Yours

Alex Starace

On one of my recent assignments for New York University Archives, my boss told me, “Well, Alex, we need someone to go to the Physics Department and box some things up.” Fair enough, I thought. She led me and a coworker over to the building, got out a key and opened an office on the sixth floor. We stepped in. It looked like the man had just gone off to lunch. There were papers and a mug on the desk, some chairs scattered about, a rickety kitchen table in the center of the room (presumably used for consulting over problems), and stacks of books everywhere. LARRY SPRUCH was emblazoned across the nameplate on the desk. We were to box up everything that was labeled for archives. Already, I was suspecting....

Before long, my coworker said to my boss, “So where’s this guy moving to?”

My boss: “He moved upstairs.”

“Just one floor up?”

“No...”

“Where, then?”

“Waaay upstairs ... to heaven.”

“Ah.”

This was creepy. I felt like one of those people who are paid to scrub blood off the sidewalk after a murder so that citizens can walk up and down 59th Street without a second thought; I would clean out the office, a bright-eyed young professor would move in, and Larry Spruch would be confined to Row H, Columns 4 – 17 in a storage warehouse somewhere. It was disconcerting.

Worse still: the scene before me was uncannily familiar. My father is a physics professor at the University of Nebraska, so I grew up around walls made of painted concrete cinder

blocks, dusty shelves, filthy windows, and stacks of journals. Here, too, there were papers and books everywhere, and scant few photographs or adornments. Everything was horribly dated – the chairs from the sixties, a rotary phone on the desk, carpet from three decades past, utilitarian metal bookcases, a 1973 poster of Universitat Heidelberg affixed to one wall, a panoramic view of the Alps on another. If there is a physics professor aesthetic, this is it: cluttered, filthy, yet Spartan. No comforts, amenities, or bling. Just stacks of articles, some flat surfaces on which to write, a computer or three, and an obligatory poster or two on the wall.

My coworker mumbled, as she was sorting through the papers, “This is all physics equations, this is so far over my head...” Not for me. Left and right I was having flashbacks. The thick white tome “Quantum Mechanics: Volume One” was comforting – a visual touchstone from my pre-teen years, when I’d spent hours sitting around my father’s office. Thirty-five years of “Reviews of Modern Physics” arranged across a bookshelf – my father has the same set up. The ancient Swingline stapler on Mr. Spruch’s desk was the exact same model I use in my apartment – I got it from my family’s “extras” pile when I moved away to college. At first these affinities were frightening, but soon they became comforting. For example, there’s the indelible charm of a paper entitled “Mechanisms for Charge Transfer (or For the Capture of Any Light Particle) at Asymptotically High Impact Velocities.” I love this title because, like many physics papers, it’s mind-numbingly straightforward and yet highly esoteric.

This wasn’t just a scrapbook of Larry Spruch’s life – it was a scrapbook of my life. Let me describe some more: I found the cover of a 1965 booklet “Advantages of the Boulder-Denver Area for the 200-300 BeV Proton Accelerator.” The

whole thing was very familiar: my father took a sabbatical at the University of Colorado at Boulder for a year in 1992-93. Our family lived there that summer. Throughout the office I was finding these connections. And then, towards the end of my assignment, I found a list of "Conference Participants." The sheet of paper had been separated from others, so it was unclear what conference it was for or when it had taken place, but, as I expected, my father, A. F. Starace, was one of the participants. The description "Strong B Fields," was scrawled next to his name. Evidently, that's what he presented. Also amongst the conference participants were P. Burrow (whose daughter used to babysit me), U. Fano (I threw up on him in a London taxi cab, summer of 1985), D. J. Burns (whose daughter I went to high school with), and J. A. R. Samson (a Scottish man, whose wife always insisted I call her "Auntie Mary"). I had not thought of these people in years.

Of course, of the three of us working on the project (myself, my boss, my coworker), I was the only one who had any personal interest in the office or the papers. My fascination with the room was not why we were archiving certain of Mr. Spruch's documents. His work on Casimir Interactions

(to take one example from his career) is worth keeping so that future physicists can look it up. And perhaps someday, social historians will want to re-create a physicist's office just so that people can see what such an office looks like. As an archivist, I'm sympathetic to these goals, though, in this particular instance, they're only passingly important to me.

From my perspective, Spruch's office functioned more like a community center, or a 3-D scrapbook. The office hammered home how abnormal my formative years had been. It was good to stumble across it again – there's a lot of fun and perspective in such coincidences. Plus, there's a sense of community and pride – particularly pleasurable was when I called up my dad a few days later and asked him if he knew of some guy named Larry Spruch.

"Oh, yeah, sure," he said, "I definitely do. Actually, he died recently..."

My response: "Yes, I know."

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How to Solve Global Warming

Art Hobson

We must get serious about using technology wisely, or humankind will not pull through the technology transition that began with the industrial age.

The clearest example is global warming--our biggest challenge to date. We can no longer prevent it, but there's still time to ward off its worst consequences. This will be neither cheap nor easy, but it's doable. Britain's authoritative Stern Review on the Economics of Climate Change states that global warming can be addressed adequately for less than one percent of global domestic product every year, while if not addressed adequately it will cost 20 percent of world GDP and be as devastating as World War II. We can afford to address the problem, but we can't afford not to.

What must we do? Global temperatures have already risen 1.35 degrees Fahrenheit since 1900. NASA's global warming expert James Hansen estimates that another 2 degrees of warming will bring us to a tipping point beyond which irreversible polar ice cap melting begins, and 1.25 degrees of that is already "in the pipeline" because of the delayed effects of the global warming pollutants already in the atmosphere. The margin of error is thin.

To prevent disaster, Hansen and others calculate that we

must hold atmospheric carbon dioxide concentrations to less than 450 molecules per million air molecules (450 ppm). Since 1900, fossil fuels and forest clearing have driven concentrations upward from 280 to 380 ppm, and rising at 18 ppm every decade. So another 3 decades of "business as usual" could get us in big trouble.

The best summary of solutions I've seen comes from Robert Socolow and Stephen Pacala, leaders of the carbon mitigation initiative at Princeton University, where Socolow is a mechanical engineering professor and Pacala an ecology professor. They offer 15 global strategies, called "wedges," for reducing carbon emissions during the next 50 years, any 10 of which would suffice. Here are the strategies, grouped under 5 larger categories.

Efficiency and conservation: Increase the fuel economy of 2 billion cars from 30 to 60 mpg; drive 2 billion cars not 10,000 but 5,000 miles a year; cut electricity use in buildings by 25 percent.

Power generation: Raise the efficiency at 1,600 large coal-fired plants from 40 to 60 percent; replace 1,400 large coal-fired plants with gas-fired plants. Carbon sequestration (coal plants pumping their carbon dioxide emissions into

underground storage): Install sequestration at 800 large coal-fired plants; install sequestration at coal plants that produce hydrogen for 1.5 billion vehicles; install sequestration at coal-to-liquid fuel plants.

Alternative energy sources: Increase nuclear power threefold to displace coal; increase wind power 40-fold to displace coal; increase solar power (photovoltaics, solar-thermal electricity generation) 700-fold to displace coal; increase wind power 80-fold to make hydrogen for zero-emission cars; drive 2 billion cars on ethanol.

Agriculture and forestry: stop all deforestation; practice “conservation tillage” (seeds are drilled into the ground without plowing) and other actions that conserve soil carbon.

None of these are easy, but all are technically and financially feasible. Any ten “wedges” would suffice.

We could accomplish many of these wedges simply by practicing what many of us regard as the first principle of environmental economics: Technologies must incorporate environmental “externalities” into their own balance sheets. Here’s a local example: The Southwestern Electric Power Company should not be allowed to freely exploit Fayetteville’s scenic beauty with their proposed giant electric poles. Swepco should bury the lines, and they and their customers should bear the financial burden.

What can you do? Here are a few suggestions: Have at least one car-free day every week (the car is most people’s biggest energy consumer, by far), walk to work, bicycle to work, live near your work, buy a fuel-efficient car, car-pool, support higher gasoline taxes, question the “need” for new roads, avoid car-oriented big-box stores, oppose I-540 widening, support mass transit, support a regional train, support sidewalks and trails, support higher impact fees, support compact communities, support infill, oppose unsequestered

coal plants, conserve electricity, conserve paper, conserve water, use compact fluorescents, insulate your home, live in a small house, stop at two children, support family planning, teach environmentalism to your children, recycle, generate less trash, don’t litter, criticize people who litter, pick up other people’s litter, buy less stuff, buy stuff that’s durable and repairable, don’t buy over-packaged stuff, don’t waste stuff, eat low on the food chain, eat less, buy organic products, take a cloth bag to the store, patronize the Farmers’ Market, buy local and regional products, and follow the serious (not celebrity) news. There are many more. Nobody does them all, but do some of them and add more as time goes by.

It all comes down to one thing you need to do: Develop an attitude of thoughtfulness—reverence—toward our planet. These little actions go a long way. For instance, if every American home replaced just ten light bulbs with compact fluorescents, each person would save \$300 in energy costs and more importantly our nation would prevent carbon emissions equivalent to 8 million automobiles.

Support the McCain-Obama-Lieberman national plan to reduce emissions by two-thirds by 2050. Support the Arkansas bill to establish the “Governor’s Commission on Global Warming,” the first global warming legislation ever proposed in Arkansas. Arkansas is one of only two states (along with South Carolina) that presently has no official state activity regarding global warming.

The world can solve this problem. But neither business as usual nor politics as usual will do. It’s time for each of us to get involved.

Reprinted from Art Hobson’s regular column in the Northwest Arkansas Times of Fayetteville, NWA Times 17 Mar 2007

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NEWS

Concerns Voiced Over Future of Space Science Programs

“It is both ‘the best of times and the worst of times’ for NASA’s space science programs. We have witnessed a whole series of exciting events in recent months. The bad news is that while those accomplishments were enabled by the nation’s past investments in NASA’s science activities, the outlook for the needed future investments is not good if present trends are any indication.” — *House S&T Space and Aeronautics Subcommittee Chair Mark Udall (D-CO)*

The dichotomy between the plethora of exciting scientific results today and a possible dearth of results in the future, if current budget trends continue, was the subject of a May 2 hearing of the House S&T Subcommittee on Space and Aeronautics. Scientists representing several space science disciplines warned that NASA’s FY 2008 budget request and future funding plans will be detrimental to its science programs. They particularly decried cuts to Research and Analysis (R&A) funding and to suborbital, small- and medium-sized science missions that provide a career path for

young investigators. The hearing, which focused on space science programs within NASA's Science Mission Directorate (SMD), also highlighted concerns over the increasing costs of access to space, the upcoming elimination of an important launch vehicle for smaller missions, poor historical estimates of mission costs, and the burden of oversight and risk reduction. Life and microgravity science programs were not discussed, nor was earth science, which will be the topic of a forthcoming subcommittee hearing.

NASA's fiscal year 2008 request for its space science programs is \$4.0 billion, with \$1.4 billion for Planetary Science, \$1.1 billion for Heliophysics, and \$1.6 billion for Astrophysics. According to subcommittee chairman Mark Udall (D-CO), the Administration has cut another \$4 billion over five years from the Science Mission Directorate's funding profile, compared to its intentions at the time President Bush announced his Vision for Space Exploration. Ranking Minority Member Ken Calvert (R-CA) pointed out that "severe budget challenges" facing NASA's human space flight program forced the agency to "remove future budget growth" from its science programs "in order to address more pressing needs." The Administration plans to restrict budget growth for NASA science programs to one percent per year over the next few years, which is an effective reduction given inflation and growing launch costs (see <http://www.aip.org/fyi/2007/016.html> for details of the FY 2008 request). Several witnesses expressed disappointment that NASA science was not included in the President's American Competitiveness Initiative, which calls for increased funding for basic research in certain physical sciences areas.

In their prepared statements, the four non-NASA witnesses gave notably similar assessments of the health of their fields. "For each of the disciplines in SMD, there is a sobering downward trend in missions," said Lennard Fisk of the University of Michigan, and Chair of the National Research Council's Space Studies Board. Garth Illingworth of the University of California, Santa Cruz, stated, "If one takes a near-term view...the mission mix in Astrophysics looks fairly good... [But] the new mission pipeline is strikingly empty beyond 2009." Daniel Baker of the University of Colorado, Boulder, added, "At present, the Heliophysics Division...has a number of exciting projects... Beyond this good news, however, there are significant concerns." "The reason why we aren't all celebrating," said Joseph Burns of Cornell University, "is because, while America's planetary exploration program is indeed doing well currently, its future is quite uncertain." Burns went on to point out that "at present no planetary flagship mission is in development, an unprecedented situation."

Testifying before the subcommittee for the first time as NASA's Associate Administrator for SMD was Alan Stern.

Stern brings to the position a background in astrophysics and planetary science, and experience as a principal investigator on NASA science missions. He was lauded by the other witnesses as an excellent choice for the role. Stern said that one of his first actions in his new position was to establish an SMD Office of Chief Scientist "to provide independent technical analysis and advice" regarding science issues. His statement highlighted the role of science in the Vision for Space Exploration: "I am an enthusiastic advocate of human exploration and believe that a strong science program...is important to maximizing the benefits to the Nation of such human exploration." Stern's top goals for the next five years include making "strong progress" in advancing the priorities of the decadal surveys for each discipline; improving management and efficiency to free up more money for science missions; and increasing the scientific yield of the Vision for Space Exploration. "I am committed," he stated, to "bringing to NASA and the Congress the best possible slate of programs and program success within the significant resources already available."

Stern's concerns aligned with those expressed by the other witnesses. All worried about rising launch costs, inadequate mission cost-estimation procedures, and the need to increase support for R&A and maintain a mix of small- and medium-sized missions. They agreed that small, inexpensive projects such as those utilizing balloons, sounding rockets, or aircraft were invaluable for preparing NASA's future workforce, ensuring that young scientists and engineers get hands-on experience. Illingworth remarked that R&A was "a grab bag" of many elements, including theory, technology development, workforce training and data analysis. Asked whether a certain percentage of a project budget was appropriate for R&A, the witnesses replied that it was discipline-dependent. Baker pointed out that the Science Mission Directorate plans to undertake a systematic review of this issue.

Illingworth also testified that, in the past, mission cost estimates were often "unrealistic and incomplete," leading to "a gap between what we wanted to do and what we can do." He said this concern has been recognized by both the agency and the science community. Stern commented that NASA Administrator Michael Griffin has instituted new policies requiring higher confidence levels for project costs, and allowing principal investigators to be removed from heading missions if cost growth gets out of control. Stern also suggested that principal investigators consider reducing their research and teaching workloads during the critical stages of mission development. Baker pointed out that launch costs could increase dramatically when Boeing phases out its Delta II launch vehicle. The panelists agreed that NASA needs to find a way to maintain such a critical payload launch capability. They also suggested that the bureaucratic overhead involved

in mission risk reduction, while appropriate to manned missions, was perhaps unnecessary for unmanned missions and led to additional cost growth.

In response to Stern's contention that available funding could be leveraged and stretched further by increasing international collaborations, the other witnesses raised the issue of ITAR export control regulations. Burns said they "hamstring" collaborations, Baker said they were "inappropriately stifling," and Fisk called them "a nightmare" and "probably the single biggest impediment" to international space science collaborations.

Udall captured the sense of the hearing when he said, "at the end of the day... if we are going to ask our nation's space science program to undertake challenging and meaningful initiatives, we are going to need to provide the necessary resources." He and full Committee Chairman Bart Gordon (D-TN) sent an April 19 letter to the President, outlining concerns "about the mismatch between the resources being provided to [NASA] and the tasks that it is being asked to undertake." They continued, "We echo the views of other members of Congress who have expressed their interest in meeting with you on this important matter, and we hope that there will be the opportunity for all of us to meet with you in the near future to discuss how best to realize our common goals."

FYI #47

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OSTP Director John Marburger on Science Policy and Budget Issues

Office of Science and Technology Policy (OSTP) Director John Marburger addressed the AAAS Forum on Science and Technology Policy in early May. This was Marburger's sixth consecutive address to this annual forum. Selections from his remarks follow on policy issues, earmarking, the outlook for funding, the impacts of the doubling of the NIH budget, and new sources of funding for university-based research.

Science Community Consensus on Policy Issues:

"Ultimately the science posture of a nation expresses itself in the myriad activities of its scientists and engineers, students and technicians - activities that may or may not sum to a coherent or effective whole. No law of nature or of politics guarantees that this real-life science posture will reflect a sensible science policy. The only hope of coherence in our national science posture is for all the diverse actors to agree on a general direction and give it priority year after year.

"Such a consensus has been achieved on some important science policy issues during the past six years. Following the attacks

of September 11, 2001, the science community came together in a remarkable show of unity to support what would obviously be a difficult and protracted struggle against terrorism."

Citing previous speeches, Marburger stated: "I also raised and reinforced concerns about the negative impacts of security measures on the conduct of science, and reported on actions OSTP and relevant departments and agencies were taking to mitigate these impacts. This is a continuing area of concern that deserves constant attention from the science community. While the student visa situation is much improved, we still have serious policy challenges ahead, including concerns about a cumbersome and graceless visa process for visiting scientists, implementation of the export control regime, potential over-regulation of dual-use bioscience, and security arrangements that stifle user programs at key national laboratories.

"The good news is that there IS a consensus among nearly all actors that these are problems that need to be addressed. The danger is that with time the salience of these issues will diminish and momentum toward solutions will be lost." Marburger cited interagency committees and other organizations that have been working on issues such as biosecurity and export control regulations as laudable examples of how these issues are being resolved.

He continued: "Wide consensus also exists on the importance of federally funded science to our nation's long term economic competitiveness." After citing 'Rising Above the Gathering Storm,' Marburger commented: "Notable among its recommendations was increased funding for basic research in the physical sciences, mathematics, and engineering — areas that had stagnated while the budget for biomedical research soared. The report even recommended that investment in these areas should increase 'ideally through reallocation of existing funds, but if necessary via new funds. 'That statement is a rare recognition of the fact that federal funds for science are limited and that some programs may have to be held constant or reduced to fund priorities. The Administration's response to this consensus was the American Competitiveness Initiative [ACI], which among other things proposed doubling budgets for NSF, NIST and the Department of Energy's Office of Science over ten years."

Earmarking:

After commenting on how FY 2007 funding in the Continuing Resolution (CR) was free of earmarks, Marburger looked ahead and remarked: "What happens next will be extremely interesting. If Congress permits earmarks in its FY08 appropriations bills, it will in effect be taking away the agency flexibility it granted in the Continuing Resolution, returning budgets the agencies can evaluate and use effectively to the base the President uses in his requests. President Bush has

asked Congress to cut the total amount of earmarks in half. If Congress does that for the science budgets — without removing the associated funds it granted in the CR — it would be wonderful for science.

“What Congress decides to do here will signal its priorities for research. The ACI prioritizes basic research in key agencies that have been relatively under funded given the importance of the fields they support for long term economic competitiveness. Because two Congresses have now failed to fund the first year of ACI at the level the President has requested, it is now behind schedule. The Administration’s FY08 request aims to catch up. The Administration continues to believe it is essential to rectify a long growing imbalance in the pattern of research funding affecting the prioritized agencies. Despite much good will toward the ACI, and recent actions on competitiveness bills by authorizing committees in both the House and the Senate, the fate of this important initiative remains in doubt. What these agencies need is appropriations for their underfunded basic research programs. They do not need new programs or new bureaucracy, new reporting requirements, or new constraints on how they use their funds, all of which are features of the authorization bills. My plea to Congress is that it protect the basic research aims of the ACI from suffocation under the weight of all these other trimmings — 20 new programs in the Senate bill alone.”

Future Federal Science Funding:

“I believe we can do all the R&D we need to do, and very much of what we want to do, but I do not believe we can accomplish this the way we would like to do it, namely by simply appropriating more federal funds.

“Neither this Administration nor any future one can escape the urgent demands of 21st century realities. The struggle against terrorism is real and persistent. Climate change demands attention. Globalization is bringing the problems of countries around the world to our doorstep. And we have yet to address the looming crunch of entitlement programs in our own country—funded through the relentlessly expanding mandatory portion of the federal budget.

“All these demands impact the Domestic Discretionary Budget, which for decades has not grown as fast as the Gross Domestic Product. It is an empirical fact that the science share of the discretionary budget has remained practically constant over time, so of course its share of GDP has fallen too. Many science advocates, including probably most people in this audience, have used the resulting decline in ratio of federal research to GDP to argue for bigger federal science budgets. Because of the constraints on the discretionary budget, this argument will not be effective in the long run.”

Effect of Doubling NIH Budget and New University Funding:

“Last October I gave a speech to the annual meeting of the Council on Governmental Relations in which I expressed my concern about the mismatch between research capacity and the federal resources to sustain it. I claimed that ‘the universe of research universities has expanded to an economically significant size, by which I mean that the sum of financial decisions by its individual members has an impact on the resources available to any one of them. It is not quite a zero-sum game, but we have moved into a new operating regime where the limits of the “market” for research university services are being tested.’ The doubling of the NIH budget that occurred, with everyone’s blessing, over a five year period ending in 2003, was an experiment in the rapid expansion of a broad but still well-defined scientific field. The most obvious lesson from this rapid growth is that it could not be sustained. There is a deeper lesson.

“It is clear that the doubling has had a profound impact on the nation’s biomedical research enterprise. It helps to think of this enterprise, and R&D activities generally, as a miniature economy with its own labor pool, markets, productive capacity, and business cycles. The response to the NIH doubling has been an abrupt increase in research capacity, financed not only by the direct federal investment, but by state governments and private sector sponsors eager to leverage this investment, not least to enhance competitiveness for additional federal funds. We now have an enlarged biomedical R&D labor pool — a new generation of researchers — who are populating new expanded research facilities and writing federal grant proposals in competition with the previous still-productive generation of their faculty advisors. And they are training yet another generation of new researchers who hope to follow the same pattern. I cannot see how such an expansion can be sustained by the same business model that led to its creation. The new researchers will either find new ways to fund their work, or they will leave the field and seek jobs in other sectors of the economy. This sub-economy is unregulated, and we can expect it to experience booms and busts typical of unregulated markets.

“Under the stimulus of federal funding, research capacity as measured in terms of labor pool and facilities can easily expand much more rapidly than even the most optimistic projections of the growth rate of the federal research budget. New capacity can only be sustained by new revenue sources. In this connection it is noteworthy that the federal research budget is dwarfed by private sector research expenditures. Under the pressure of increased competition for federal funds research universities are in fact forging new relationships with private sponsors, and I expect this trend to continue. . . . The economics of university based research are beginning to change to a new model with diversified sources of revenue.

“Federal science policy should encourage this change. Not only will it enable an expanded research enterprise, it will also promote development of capacity in areas likely to produce economically relevant outcomes. Moreover, economists have documented a positive correlation between industrial research investment and national economic productivity, and to the extent this correlation indicates a causal relationship, increased industrial research will be good for the economy.

“The message here is that federal funding for science will not grow fast enough in the foreseeable future to keep up with the geometrically expanding research capacity, and that state and private sector resources should be considered more systematically in formulating federal science policy.”

*Marburger's entire address may be read at: <http://www.ostp.gov/html/jhm%202007%20AAAS%20Policy%20Forum%20Final.pdf>
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Federal, State Recommendations on STEM Education

A review of STEM education programs across the federal government finds that few programs have been rigorously evaluated and little is known about their impact on students. This report, by the Academic Competitiveness Council, recommends that funding for federal programs to improve STEM education outcomes “should not increase unless a plan for rigorous, independent evaluation is in place.” Another report, released earlier this year by the National Governors Association, highlights the importance of STEM education to the nation’s ability to innovate, and calls for greater efforts by states and the federal government, in partnership, to improve STEM instruction and data tracking across the nation.

Academic Competitiveness Council Report:

In fiscal year 2006, the federal government supported 105 programs across 13 departments and agencies that focused on kindergarten through postgraduate STEM education, with an expenditure of \$3.12 billion. Also in 2006, the Deficit Reduction Act called for the establishment of an Academic Competitiveness Council (ACC), comprising federal officials with responsibility for STEM education programs and chaired by the Secretary of Education. The Council was charged with identifying and reviewing all federal STEM education programs and their target populations; assessing their effectiveness; identifying areas of duplication; and making recommendations for greater integration and coordination. After a yearlong effort, on May 10, the ACC released its findings.

According to the report, the ACC developed goals and metrics in three areas: K-12 Education, Postsecondary Education, and Informal Education and Outreach. The ACC sought the help of a nonpartisan, nonprofit organization to assess existing program evaluations. Of 115 evaluations of federal STEM education programs, the organization “found 10 impact evaluations that were scientifically rigorous, four of which concluded that the educational activity evaluated had a meaningful positive impact.” The report finds that “despite decades of significant federal investment in science and math education, there is a general dearth of evidence of effective practices and activities.” The report offers six recommendations:

1. “The ACC program inventory and goals and metrics should be living resources, updated regularly and used to facilitate stronger interagency coordination.”
2. “Agencies and the federal government at large should foster knowledge of effective practices through improved evaluation and-or implementation of proven-effective, research-based instructional materials and methods.”
3. “Federal agencies should improve the coordination of their K-12STEM education programs with states and local school systems.”
4. “Federal agencies should adjust program designs and operations so that programs can be assessed and measurable results can be achieved, consistent with programs’ goals.”
5. “Funding for federal STEM education programs designed to improve STEM education outcomes should not increase unless a plan for rigorous, independent evaluation is in place, appropriate to the types of activities funded.”
6. “Agencies with STEM education programs should collaborate on implementing ACC recommendations under the auspices of the National Science and Technology Council (NSTC).”

In a press release on the report, Education Secretary Margaret Spellings urged Congress to “focus investments in programs that demonstrate measurable effects on student achievement or fill gap sin the large portfolio of existing programs.” The 87-page “Report of the Academic Competitiveness Council” can be accessed at <http://www.ed.gov/print/about/inits/ed/competitiveness/acc-mathscience/index.html>.

National Governors Association Initiative:

The National Governors Association, chaired by Governor Janet Napolitano of Arizona, earlier this year issued an initiative entitled “Innovation America,” describing what states, working in partnership with the federal government, can do to enhance education, workforce, and innovation capacity. “In the new global economy, states need a workforce with the knowledge and skills to compete,” says the initiative. “A key to developing

these skills is strengthening science, technology, engineering, and math (STEM) competencies in every K-12 student.”

“Innovation America” offers strategies for governors, and suggestions for federal assistance, in three areas: Improving K-12 STEM education; improving postsecondary education and workforce training; and encouraging regional private sector innovation. The initiative offers the following STEM education recommendations for governors, and includes examples of specific states that have implemented such strategies:

1. “Align state K-12 STEM standards and assessments with postsecondary and workforce expectations for what high school graduates know and can do.” States should participate in international assessments and align their standards and assessments with international benchmarks; align K-12 STEM expectations with all paths students might take after graduation; and align elementary, middle and high school STEM education “to create a coherent K-12 system.”
2. “Examine and increase the state’s internal capacity to improve teaching and learning.” States should use international benchmarks to evaluate their capacity; improve K-16 data systems “to track the STEM preparation of students;” develop strategies to communicate to the public “the urgency of improving STEM;” develop or charge P-16 councils to spearhead alignments of the STEM education system; support “promising new models of recruiting, preparing, certifying, compensating, and evaluating teachers” in STEM fields; and “support extra

learning opportunities” in STEM fields.

3. “Identify best practices in STEM education and bring them to scale.” States should support and expand the availability of specialized STEM schools; develop standards and assessments in technology and engineering as well as math and science; support development of high quality STEM curricula; and develop standards for Career and Technical Education programs.

The initiative also includes “Innovation America: A Partnership, “which outlines complementary recommendations for what the federal government can do to assist, enhance and accelerate state actions in the areas of education, economic development, and workforce training. In the area of education, the initiative seeks federal support for: student tuition assistance for STEM and critical foreign language career paths; recruitment and retention of high-quality teachers; STEM education improvement grants; high school redesign enhancement; grants to Governors for P-16+ Councils and Data Systems; and international benchmarking. Further information on “Innovation America” can be found at <http://www.nga.org> on the left-hand side under “2006-2007 NGA Chair Gov. Janet Napolitano’s Initiative.

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REVIEWS

Nuclear Shadowboxing Vol. 2: Legacies and Challenges

By Alexander DeVolpi, Vladimir E. Minkov, Vadim E. Simonenko and George S. Stanford, (Fidlar Doubleday, Kalamazoo, MI, 2004)

I have already reviewed a descriptive part of this book. Now, A. DeVolpi, V. E. Minkov, V. E. Simonenko and G. Stanford, to be mentioned henceforth as the “gang of four” or G4, came up with a prescriptive part. This work is clearly a labor of love for the authors. Yet, as in the previous volume, self-critical restraint is sometimes missing.

I might say that the authors did a significant editing job. In comparison with the first volume, this volume dispenses with the disparate fonts for the boxes, puts sections headings

and chapters in a logical sequence, etc. However, my main concern about Volume 1 was not with typographic conventions, but more with organization of content. Disorganized treatment betrays lack of clarity of thinking, and accurate tables of contents make unclear substance dimmer still. One example: the Contents section for Chapter VI alone lists more than 200 sections for 121 pages (I am not joking!) with complex page numbering. The manuscript can be significantly streamlined by omission of extraneous material such as rants on global poverty, Mattias Rust (still remember him? p. V-33), torture (p. VI-78), non-nuclear terrorism, chemical and biological weapons and so on. Information on “axis of evil” conventional armed forces creeps into the section on the Russian Federation (p. VI-35). Some of the material looks undecipherable, being put in enigmatic table with zeroes in all columns and rows (Second part

of Table 3 on p. VIa2-2), or in a table with four of five columns empty (Table 1 on p. VIIg-5). Yet, amidst this largesse, some of the omissions look puzzling; for example, who knows what are or who are Quemoy and Matsu (p. VI-31)?

As far as the book's content is concerned, the authors pretty much reiterate the existing consensus of academic physical scientists: thumbs down for nuclear weapons, thumbs up for nuclear energy. Their prescriptions for enhancing nuclear security range from what this author considers a reasonable but missed opportunity ("de-MIRVing of the strategic missiles"), to the naïve ("prohibition of putting countermeasures and decoys on missiles") (Table VIIg-1),¹ but all within the prevailing thinking of the academic nuclear establishment. I must mention, and not just with respect to the authors but also to other oft-cited speakers on nuclear disarmament such as Richard Garwin or Joseph Biden, that the Anglo-American viewpoint can be very remote from the thinking in the rest of the world. For instance, the political consensus in Russia on whether the country should maintain relatively large and survivable nuclear forces, which did not exist in the first half of the nineties, emerged practically overnight after NATO bombed Yugoslavia. From what I know, this might also be the case with India.

I have a more difficult time judging the G4 ideas on the peaceful uses of nuclear energy, which they embrace too enthusiastically for my taste. While I am hardly an anti-nuclear zealot and consider nuclear power plants as an important contributor to the future energy mix, some of the authors' projections concerning the viability of the nuclear option seem wildly optimistic. For instance, G4 considers scuttling nuclear ships in deep seas as a safe method of disposal. The possibility of using ocean trenches was explored in the much less environmentally sensitive 1960s and, as I recall, was rejected on the grounds that underwater currents and oceanic turbulence would insure mixing. The statistics on the level of federal R&D expense per kilowatt-hour of energy does not look credible to me (for instance, a factor of 11 favoring of oil vs. nuclear R&D) and is altogether laughable for photovoltaics (p. Ve-2).² It appears to have been taken straight from the nuclear lobby's publications.

The chaos grows when we approach the authors' narrow field of expertise, probably because they feel more secure. For instance, in the otherwise very useful Table 2, (see also pp. VI f4-1 and VI f4-3) one spots the figure 94% of the fissile isotope's fraction for weapons-grade plutonium, while on an adjacent page the authors list it as 20% (p. VI f4-2). In fact, both figures could be accurate if G4 would consistently follow their own distinction between weapons-quality (considered as such by the US standards of nuclear weapons production) and weapons-grade material. The latter is deemed dangerous

by the IAEA as indicative of the intention of potential proliferators to build a weapon, but not necessarily useful for the bomb. Some of the reasoning (for example, "especially the rapid excursion that is characteristic of explosive assembly," p. VI f5-1) seems too involved for an intended reader of a book that also takes the time to explain the conversion of pounds to metric tons (p. VI f1-3).

What I hope for from the G4 would be a new book where they could describe their own experiences spent in the US and USSR nuclear complexes. Such a book could be more personal, containing anecdotes and professional jokes. This final volume could be a towering monument for the many lives spent in building the nuclear weapons legacy, which they now take so much effort to undo.

- 1 *All nuclear powers, except for the US with their extensive plans of strategic defense, would certainly view this impediment as a cheap American ploy to undermine the credibility of their nuclear deterrent. Similarly, another proposal, namely a separate storage of nuclear warheads from the delivery systems, would only increase suspicion that the United States plans to attack the delivery vehicles of the counterparty by conventional smart munitions before they could be used in a counterstrike.*
- 2 *My own, very conservative, estimate (assuming zero private funding for nuclear energy research but including it in oil and gas) suggests roughly \$80/MBTU (million BTUs) of R&D money for fossil fuels and \$126/MBTU for nuclear energy in 2005/2006, i.e. a factor of 1.5 in the opposite direction. Comparing photovoltaics with oil and gas on this basis seems as reasonable to me as comparing nutritional caloric yield per dollar in corn syrup and in caviar. You cannot plug a gas pump to a space station.*

Peter B. Lerner
Quantum Transistor LLC1

Bomb Scare: The History and Future of Nuclear Weapons

By Joseph Cirincione, Columbia Univ Press, New York, 2007

As the UN and world powers struggle with enrichment and proliferation concerns in Iran and North Korea we would be wise to look back on and learn from six decades of history as to how the nuclear world has come to be what it is. This eight-chapter book reviews the history of nuclear weapons and nonproliferation agreements and offers some solutions to the threat of nuclear terrorism as well as ideas to address lack of security of the nuclear fuel supply and preventing the development of new nuclear-weapon states. Cirincione has extensive experience in nonproliferation issues. He is a former staff member with the House Committee on Armed Services, spent eight years as Director for Nonproliferation at the Carnegie Endowment for International Peace, and is currently Vice President for National Security at the Center for American Progress.

The first three chapters review the development of nuclear weapons from the discovery of fission through the North Korean test of late 2006, the evolution of the nuclear arms race, and the treaties and institutions that have emerged to control the spread of nuclear weapons. While these chapters provide a good general review of these matters, this reviewer caught some technical errors. A discussion of assembly timing issues in the gun and implosion mechanisms of Little Boy and Fat Man are sufficiently garbled as to indicate that the author is unaware of the crucial role of spontaneous fission. One finds the patently incorrect assertion that the Sun will be able to synthesize elements as heavy as sulfur. These are quibbles in comparison to the grand themes of nonproliferation and disarmament, but one would expect an author of this experience to be more careful: policy issues can and do hang on technicalities.

In Chapter 4, his longest, Cirincione frames the debate of the future of post cold-war nonproliferation initiatives by positing five factors that can act as incentives/disincentives for states to acquire nuclear weapons, illustrating each with historical examples. In order, these are security (self-security/alliances with stronger powers), prestige (great-power aspirations/ nonproliferation leadership), domestic politics (interest-group agendas/grass-roots citizen campaigns), technological determinism (scientific prowess/engineering difficulties), and economics (cheaper than conventional forces/opportunity and environmental costs). Chapter 5 applies this mix of factors to an assessment of today's nuclear world. The author credits the START and INF treaties with reducing the threat of global thermonuclear war to near zero, leaving us with four current threats: nuclear terrorism, arsenals on hair-trigger alert, the prospect of new nuclear weapons states, and the collapse of the nonproliferation regime.

The terrorist threat revolves largely around issues of security of Russian supplies of weapons-grade materials and the specter of instability in Pakistan. Cirincione dismisses North Korea in this context by arguing that that country is not likely to give away what its leadership sees as its most precious security jewel, an argument this reviewer does not find entirely convincing. The hair-trigger situation is aggravated by deteriorating Russian infrastructure. The threat from new nuclear weapons states may not lie so much in those states themselves but in their catalyzing regional arms races. The author argues that the double-standard of the US investing in new warhead designs while encouraging other powers not to go nuclear will only increase the prospect of a world with more nuclear-armed states. His deepest concern, however, is the potential collapse of the non-proliferation regime, a prospect for which he lays much blame with the current US neoconservative policy of interventionist regime change. Critics of this policy will find much to their liking in a laundry list of policy failures detailed in Chapter 6.

Chapter 7 takes up what the author offers as good news about nuclear proliferation: over the last 20 years the number of warheads has been cut back from about 65,000 to 27,000 while the number of ballistic missiles has also been reduced. More than once he emphasizes that the number of countries with nuclear weapons and programs has declined, but the proffered count includes countries such as Canada, Belarus, Kazakhstan and Ukraine that never had indigenous programs.

In his last chapter, Cirincione offers solutions to the threat of nuclear terrorism as well as the issues of securing the nuclear fuel supply and preventing new nuclear states. This material is the weakest of the entire book. Strengthening the Nunn-Lugar program is an obvious way to help thwart nuclear terrorism, but this is accompanied by the suggestion of ending the use of all weapons-usable material in civilian power, research, and naval reactors. Laudable goals, perhaps, but no alternatives to these systems are offered. A multi-national system of assured nuclear fuel services is proposed, a sort of updated Baruch plan minus any requirement or incentive for current nuclear weapon states to decrease their arsenals. The author is silent, however, concerning the resistance such a scheme would face in view of US suspicion of a UN-administered program and the vested interests of producers and consumers of nuclear materials and weapons. He also does not address what to do with waste fuel, not a gram of which seems likely to see the inside of Yucca Mountain anytime soon. A suggestion that Israel consider abandoning its nuclear capability without proposals for security guarantees from its neighbors seems divorced from reality.

Despite these criticisms, Cirincione gives us much to think about; this book should be required reading by anyone interested in these issues. In the end, this reviewer shares the author's sentiment that stronger international nonproliferation, disarmament, and technology-transfer agreements backed up by meaningful enforcement are likely our best hope for preventing a new wave of proliferation. But given the state of the world today I am not as optimistic as he that these might soon come to pass.

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Physics of Societal Issues: Calculations on National Security, Environment, and Energy

David Hafemeister (New York: Springer, 2007) ISBN 978-0-387-95560-5, xvii + 487 pp, € 114.95.

Perhaps at no time in history have big-picture societal issues such as national security, climate change, and energy supply demanded such broad understanding of underlying physical principles as they do now. David Hafemeister's Phys-

ics of Societal Issues is a call by a physicist to the physics community to join in improving the science-and-public policy process. This 16-chapter book is subdivided into three major sections that deal respectively with the fundamental physics of national security (nuclear weapons, missiles, missile defense, treaties, and proliferation), environment (chemical and nuclear pollution, climate change, effects of EM fields), and energy (usage, buildings, solar and renewable energy, efficiency, transportation, and economics). Indeed, it is, as advertised, essentially three texts under one cover. Hafemeister is exceptionally qualified in all of these areas: his resume' lists, among many other activities, stints as a Science Fellow in the physics division at Los Alamos, as an American Association for the Advancement of Science Congressional Fellow, as a Special Assistant to the Under-Secretary of State for Security Assistance, Science, and Technology, as a professional staff member on the US Senate Committees on Foreign Relations and Governmental Affairs, and as chair of both the APS Panel on Public Affairs and the Forum on Physics and Society. He has published extensively on areas as diverse as the nuclear arms race, renewable energy, global warming, and the biological effects of EM fields.

As described in its preface, *Physics of Societal Issues* addresses the need for a text that analyses the physics of its three main topics. It is written for scientists and engineers with a solid grasp of baccalaureate-level physics who want to be able to calculate approximate but useful answers in a Fermiesque "back-of-the-envelope" way to help inform and enhance the debate on these issues.

This is not a textbook in the conventional sense of the word. Each chapter is divided into a number of sections and subsections where relevant physics is applied to a single concept that is part of a larger issue. Mathematical expressions are not derived but simply stated and then applied. The breadth of the physics, mathematics, and general knowledge exhibited is staggering; one can learn a lot by simply choosing a section at random and dipping into it. A very incomplete list of topics, with applications in parentheses, includes the Coulomb self-energy of an electric charge (fission energetics), the rocket equation and parabolic trajectories (ICBMs), error propagation and Gaussian distributions (missile targeting), the optics of laser-beam spread (space-based lasers), kinematics (railguns), the convolution and Fourier addition theorems (digital image processing), the Stefan-Boltzmann law (IR reconnaissance), pH chemistry (acid rain), adiabatic expansion (monitoring of explosions), diffusion (pollutants and power-plant plumes), chemical reactions and rate equations (the ozone layer and CFCs), radiation exposure units (theory of excess cancers), heat capacity and thermal conductivity (heat loading in geological repositories and household

energy efficiency), economics (carbon taxes and elasticity of demand), Ampere's Law (effects of power lines), statistics (risk assessment), exponential growth (energy consumption), thermodynamics (power-plant efficiency), atmospheric extinction (solar flux), rotational dynamics (flywheels), and drag forces (automobile efficiency). This reviewer can think of only a very few areas of his undergraduate physics curriculum that were not touched on in some way or other in this book.

Each chapter is accompanied by about 20 problems in which readers are challenged to apply concepts and make estimates. These range from exercises designed to build familiarity with unit conversions (what is a Dobson unit in ozone-molecules per square meter?) to full-scale calculations such as the energy loss from a house of a given size with given window-area and insulation characteristics; no answers are supplied, however. Appendices offer chronologies on the development of nuclear arms and energy and the environment, as well as on units (including tongue-in-cheek humor units), symbols, websites, and glossaries for each of the three topic sections. The index is likewise divided into the three topic sections, but struck this reviewer as very abbreviated.

My only disappointment was in the quality of a number of the figures. A map showing contamination from a dirty cobalt-bomb attack on New York City is virtually unreadable and appears to contain no length-scale bar (p. 181); a diagram of ocean circulation shows both land and water masses as almost the same muddy grey color (p. 218); the key to a chart of contributions (industrial, agricultural, residential ...) to summer peak-day power use in California is printed in such a way that one cannot tell various contributions from each other (p. 366); the axes values and legend text on a graph of cost of conserved energy are blurry (p. 413). There are a number of such examples, all of which seem to involve diagrams and graphs that were adopted from other sources and that do not appear to have happily survived transformation from color printing to black-and-white. For a volume with the Springer imprint and a list price in excess of 100 euros, I would have expected better. A casual perusal revealed a few misspellings, and one technical error caught this reviewer's eye (on page 10, it is Po-210 that is used to help trigger nuclear weapons, not Pu-210), but such minor oversights are to be expected in the first edition of a technically complex work.

Hafemeister has produced a masterful and long-overdue work that should be on the shelf of any physicist interested in or who is asked to comment upon physics-and-society issues.

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The Grid: A Journey through the Heart of our Electrified World

By Phillip F. Schewe, *Joseph Henry Press*, 311 pp., ISBN-13:978-0-309-10260-5

Phillip Schewe is excellently qualified to write this popular account of the history and present status of our American electric grid, since he has been active both in physics research and in writing about science. He is a member of three quite diverse organizations: the APS, the Dramatists Guild, and the National Association of Science Writers.

Schewe gives us a fine history of the creation and development of our American grid. His history starts with Thomas Edison's 1882 creation of a square-mile direct current grid in downtown Manhattan. Then came the alternating-current and three-phase grids of Nikola Tesla and George Westinghouse. Next, Samuel Insull sold Chicago on more and more electrification, and created a financial empire that collapsed during the great Depression. Schewe balances his narrative of these stupendous scientific-engineering-business activities with philosophical quotes from Lewis Mumford and Henry David Thoreau such as the latter's "A man is rich in proportion to the number of things which he can afford to let alone."

Schewe discusses in detail two major American blackouts on 9 November 1965 and 14 August 2003. Could these serious problems be avoided with improved technology? Schewe writes (p. 145) "Achieving a grid that never crashes is like trying to reach the speed of light or a temperature of absolute zero. It can't be done." He supports his pessimistic conclusion by reference to "complexity theory," for example, analysis of avalanches in unstable sandpiles. Complexity theory is an ambitious program that tries to relate the behavior of many different complex systems. But complexity theory, I believe, does not prove that a specific complex system—such as our American grid—is bound to fail. And complexity theory just isn't in the same league as the well established theory of special relativity. Also, see Clark Gellings and Kurt Yeager's "Transforming the Electric Infrastructure" (*Physics Today*, December 2004, pp. 45-51) for their discussion of ways to improve our grid and achieve massive reduction of the probability of failure.

Although Schewe presents a fine discussion of the variety of energy sources used to power the grid, his discussion of nuclear energy suffers from our lack of firm scientific knowledge of the safety or danger of rather low doses of nuclear radiation of order of magnitude 0.1 Sieverts (or 10 Roentgens) a year. Did the Chernobyl disaster actually kill 50,000 people over the next twenty years, or only the fifty who received very large amounts of radiation? Schewe tacitly accepts governmental standards for a safe amount of radiation,

an acceptance that leads to severe problems in finding "safe storage" of radioactive waste for many thousands of years. I can see why in his popular account Schewe does not want to open the can of worms of the linear hypothesis vs. threshold for radiation damage. But we scientists have to open this can of worms, even though we still don't know what to do after we've opened it.

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Editor's Comments, continued from page 1

pieces in this issue address that history: one by my co-editor on the "credit" for development of integrated circuits, the other a reminiscence of the life of a specific physicist – who happened to be one of my favorite undergraduate teachers several decades ago. Another of our major concerns is the issue of resources and the environment. These are addressed in Hobson's Commentary as well as the first two News items by Leath and by Jones. And, of course, we are concerned with education – both for future scientists and for the general society. The second item by Leith concerns the role of the Federal government in science education while the article by Doppke (a recent student of mine in a modern physics course for secondary school educators) deals with the constraints on science teaching imposed by students' religious backgrounds, a subject I have touched on here previously (*Two Brains: A No-Brainer*, *Physics and Society*, January, 2005).

I hope you find this issue, short as it is, interesting and useful. Please consider the possibility of your own submissions to your journal.

—A.M.S.

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

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