

PHYSICS AND SOCIETY

APRIL 2005 ISSUE

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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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Forum Affairs

Hard vs. Soft "Physics and Society"

As you are aware, several years ago we reduced the number of issues of Physics and Society that are printed and mailed to all members of the Forum from four to two in order to reduce our yearly costs to less than our income. (All four yearly issues are available on our web site, <http://www.aps.org/units/fps/newsletters/index.cfm>) We now spend approximately \$12,000/year of which approximately \$8,000 is for our two printed newsletters. The other costs are primarily for our April Executive Committee meeting and travel expenses for invited speakers to FPS-sponsored sessions at the March and April meetings. Our income in 2004 was approximately \$20,000 from our share of dues, investment income, and the March/April meeting registration fees. We currently have accumulated \$33,000 in our account. The Executive Committee has begun to explore ideas for how best to spend our extra income (eg. sponsorship of student research relevant to the Forum) and we would like your suggestions. Please send them to me via email. I look forward to hearing from you.

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Report from the FPS Executive Committee

On March 1, 2005 the Executive Committee held a teleconference attended by Mark Sakitt, Bo Hammer, Al Saperstein, Mark Goodman, Joel Primack, Caroline Herzenberg, George Lewis, Sherrie Preishe, Andrew Post-Zwicker. The primary purpose of this meeting was to discuss the FPS budget surplus brought about from decreasing the number of printed copies of our newsletter from four to two (with all four yearly issues published on our web site). Besides the newsletter, our other typical expenses are related to FPS-sponsored sessions at the March and April meetings. Currently, our expenses are on the order of \$8k less than our income (from membership dues and our share of APS investment and meeting revenue.) During CY '04, we used some of our surplus to give \$10k of support to the new Sakharov Prize.

The idea that generated the most interest was to support a fellowship for undergraduate students that perform research of interest to the Forum. Another was to create a summer school for undergraduates on topics of relevance to the Forum. A committee consisting of myself, Bo Hammer, Carol Herzenberg, and Al Saperstein was formed to explore these ideas. Any input from the membership would be appreciated and can be sent to azwicker@pppl.gov.

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Editor's Comment

When a great tree falls in the forest, a great void is created, a space which will eventually be filled by new trees, nurtured by the remnants of the life processes of the departed giant. It will be a long time, if ever, before one of the successor trees reach the stature of the departed giant. A giant of physics and society has just fallen, one who shaped physics and its societal implications from the mid-twentieth century and was still productively active in the twenty first. We shall not see another Hans Bethe for a long time.

Trees, non-sentient beings, passively benefit from their heritage via the nutrients sucked up by their roots. We sentient beings must actively examine our roots in order to benefit from the past and grow into the future. The worlds of theoretical physics and astrophysics carry on the examination of the scientific contributions of Hans Bethe via their continued active research. *Physics and Society* hopes to further the non-scientific contributions of physics to society by examining Bethe's contributions to furthering the productive interaction between physics and society. At the suggestion of W.K.H. Panofsky, we intend to publish a series of reminiscences of interactions between society and the world of physics in which Hans Bethe played a major role. The first three contributions, by Profs. Panofsky, Drell, and Salpeter, are featured in this issue. We hope that those of our readers who have had some experience or knowledge of Bethe's efforts and contributions to science and society will submit their considered thought on the topic to this journal for publication - as letter, commentary, or article - in future issues.

Turning to another, related news item of importance, we note that our society's commitment - as manifested by our Congress - to a growing support for science seems to be diminishing, as is illustrated in the recent report, FYI #27, of the American Institute of Physics, written by Richard M. Jones. FYI #27 covers remarks by two senators with jurisdiction over the NSF in which they voice their support for the NSF, as well as their disappointment at the current funding levels for the agency. Senator Christopher Bond (R-MO) mentioned the disparity between the funding levels for biological sciences vs. physical sciences, and added, "...we are jeopardizing the work of the National Institutes of Health because we are undermining the physical sciences [via inadequate funding of the physical sciences], which provide the underpinning for medical technological advances." In response to the Bush Administration's request for a 2.4% increase for NSF in FY 2006 over the current year, Bond said, "Sadly, the budget request for NSF does not provide it with adequate resources to meet its mission....We have fallen off the path for doubling NSF's budget...." Senator Barbara Mikulski was equally disapproving,

"This barely keeps pace with inflation. Most disturbing is the cut to education programs...Senator Bond and I are committed to doubling the NSF budget over five years. We have increased NSF's budget by an average of 10% over the President's budget for the last several years. But this Administration has broken its promise to NSF. In 2002, the President signed the NSF Authorization into law. It authorized a doubling of the NSF budget between 2002 and 2007. In 2006, NSF is authorized to be funded at \$8.5 billion. Yet the President's 2006 budget funds NSF at \$5.6 billion— 34% below where it should be."

Chairman Bond had the following to say to the research community in the U.S.,

"This must mean a greater effort by the research and high-tech sector in advocating and 'selling' the virtues of NSF to the general public....come out of your labs, out of your think tanks, and let people know how important this funding is."

This diminishing support may be due to a lack of any current "giants" of science - at least as perceived by the public. More likely is the evident growing distrust of the scientific enterprise itself: the public doesn't trust "experts", especially when these experts tell it things it doesn't wish to hear. The

public expects to reap the medical and technological benefits that science has to offer without accepting the constraints, world views, and thinking processes that necessarily accompany them. Congress has most recently shown its disdain for judicial, medical, and ethical "end-of-life" expertise in the Terri Schiavo case. Not only are evolution and "big bang" cosmology disbelieved in many popular non-science institutions, it now turns out that even some science museums are refusing to show IMAX films on earth science because their lay focus groups perceive that the films may link volcanism to the possibility of evolution. Thus the future making of such films, and hence the scientific education of the public, is jeopardized.

All of this in a society with more formal and higher level study of science, by the general public, than has ever been seen before.

Clearly, as we currently teach astronomy, biology, chemistry, physics, etc., we are not teaching science to many (most?) of our students. It's time for us to put less effort in arguing for the number of science courses our citizens should have completed and become more concerned with what is actually taught in those courses. It's time to start teaching science as well astronomy, ,..., zoology..

A.M.S.

ARTICLES

An Episode among the Many Contributions of Hans Bethe to Physics and Society

*Wolfgang K.H. Panofsky*¹

When President Eisenhower concluded that further development and spread of nuclear weapons had to be stopped, he was persuaded that an international ban on nuclear testing would be a major step toward this goal. Since the verifiability of such an agreement was in dispute, he embraced the idealistic concept that scientists from the states in an adversarial relationship should first meet to establish a technical basis for monitoring the cessation of nuclear weapons testing. This would lay the foundation for subsequent negotiations between politically instructed diplomats with the goal to attain a comprehensive nuclear test ban treaty. As a member of the President's Science Advisory Committee (PSAC), Hans Bethe played a key role in developing this concept and its subsequent implementation. He chaired a subcommittee that reported on the diverse technical tools suitable to monitor nuclear test explosions conducted in the atmosphere, under water and underground. Methods analyzed were seismic detection, radio-nuclei sampling, underwater sound detection and the like. This committee became widely known as the "Bethe Panel."

Following the completion of his report and other studies on the military significance of the test ban, PSAC advised the President that he should go forward with the proposal to convene a "Conference of Experts." The Soviet Union agreed to the proposal; the resulting conference composed of scientists from the United States, Soviet Union, United Kingdom, France, Canada, Czechoslovakia, Poland and Romania convened in Geneva during the summer of 1958. The "Experts" were charged to assess the power of technical tools to detect and identify nuclear explosions. On the U.S. side, this scientific group was chaired by James Fisk, then president of the Bell Telephone Laboratory, an engineering physicist and experienced manager. The other U.S. delegates were E.O. Lawrence and Robert Bacher. They were supported by Bethe and a group of the most experienced U.S. scientists in the field independent of their political views on the test ban. The Soviet delegates were Federov (Chairman), Semenov, and Tsarapkin, who were also supported by prominent senior Soviet scientists, including Igor Tamm and others. (Tamm and Semenov were Nobel Laureates.)

It is noteworthy that, notwithstanding the vaunted objectivity of science, disagreements during negotiations tended to be in the same direction: the Soviet scientists always claimed that detection and identification were more powerful than the Americans maintained. Not accidentally, these disagreements matched the political interests of the parties: the Soviet Union opposed the necessity of extensive on-site inspections as interfering with their penchant for secrecy, while the U.S. was intent to strengthen verification. Nevertheless, in the face of these difficulties, the scientists crafted their joint report. Hans Bethe's and President Eisenhower's desire for cessation of nuclear weapons tests appeared closer to reality.

On the basis of the report of the Conference of Experts, which concluded that verification of a ban was possible within specified limits, the negotiations on a comprehensive test ban began on a political level in the fall of 1958 between the U.S., Soviet Union and the U.K. Soon after these negotiations began, new seismic information was developed as a result of further U.S. underground testing which suggested to some that the threshold of detection of underground tests would be higher than previously believed. In addition, methods of avoiding the Expert's monitoring system were proposed by the scientific opponents of impediments to nuclear testing, led by Edward Teller. They invented theoretically feasible means by which the Soviets could evade the proposed monitoring methods.

¹ The author is greatly indebted to Spurgeon M. Keeny, Jr. for correcting and complementing his memory and reviewing the manuscript.

Teller's associates, notably a group of capable physicists from the Rand Corporation in Santa Monica, California, and at the Livermore Laboratory invented two methods for such evasion: First, "decoupling" nuclear explosions underground by detonating them in the center of a "big hole." Such a cavity was to be large enough such that the pressure wave generated by the explosion would be sufficiently weak by the time it reached the cavity walls so that the elastic limit of the surrounding medium (rock or salt) would not be exceeded. Such decoupling would reduce the seismic signal by about 2 orders of magnitude, thereby severely degrading the detection and identification power of seismic instruments.

The second evasion method was nuclear weapons testing in outer space, possibly even behind the moon. One rocket would carry the nuclear device to be detonated to distances up to tens or even hundreds of thousands of kilometers; a second rocket would deploy the necessary test instruments in the vicinity of the detonation of the nuclear device carried by the first rocket, and then send the results to earth by telemetry. These evasion schemes were proposed under the implied assumption that the Soviets *would* do what they *could* do, a forerunner of the "capabilities based" approach promoted by the present Administration to justify weapons acquisition or even pre-emptive attack to counteract the perceived capability of an opponent.

The theory of decoupling through use of the "big hole" is undeniably correct; the additional, but important, issue is how to construct undetected such a cavity of a diameter exceeding a hundred meters underground and how to assure its structural integrity. A nuclear testing program in space is an issue sufficiently complex that the President's Science Advisor convened a special panel which I chaired and which included both Bethe and Teller among its members. That panel did not deny the scientific and technical feasibility of testing in outer space. However, it analyzed the effort in money and manpower such an undertaking would imply and the likelihood of success of such an enterprise. In consequence, the clear implication was that if the Soviets were to undertake such an evasion scheme, the effort diverted for that purpose from other military pursuits would be so large that U.S. security might be well served! The report was unanimously endorsed—including acceptance by both Bethe and Teller!

PSAC decided that the new information had to be presented in Geneva lest U.S. scientific credibility be degraded when that information inevitably became publicly known. In consequence, the United States government persuaded the Soviets to reopen the technical discussion to discuss "new data" that had become available since the Conference of Experts. The Soviets initially objected to reopening the technical discussions, maintaining that the Report of the Conference of Experts was the legal basis for the political discussion and therefore immutable. The U.S.'s position that the Report was a scientific-technical finding, and therefore subject to correction based on "new data," eventually prevailed. Accordingly, two further technical negotiations were convened: one called Technical Working Group I (TWG-I); the U.S. delegation was again chaired by Fisk to update the assessment of seismic monitoring including the consideration of the implications of the "big hole." The second group which I chaired (TWG-II) was to consider the monitoring of test explosions in outer space. The Soviet delegation was led by the geologist and explorer Federov.

The U.S. delegation to TWG-I agreed that Bethe should present the "big hole" idea, which he had concluded was theoretically sound, to the Soviets and he graciously agreed to take on that onerous task. The belief was that his distinguished reputation as a meticulous physicist who was known to favor a test ban would persuade the Soviets of the seriousness of the problem without suggesting to them that the U.S. was seeking to torpedo the negotiation by implicitly repudiating the Conference of Experts by showing the Soviets how to cheat! The Soviet delegation was stunned, but did not contradict the physical basis of the idea which appeared new to them. But they asked whether the U.S. delegation had political motives to bring this up. Still TWG-I reached agreement on the basic facts as to how a seismic signal would relate to the yield of a nuclear explosion, in essential agreement with the conclusions reached by the Conference of Experts.

TWG-II convened subsequently, also in Geneva and addressed the monitoring of explosions in outer space. We agreed on most of the detection methods for detecting soft x-ray and gamma ray fluxes from a nuclear explosion, and we estimated the intensity of such fluxes from weapons of various yields. In fact, during these negotiations some ideas were introduced by the U.S. delegation on the use of detection of single photons which apparently made it easier to detect such explosions than the Soviets had thought. However, the Soviet side balked at including in the list of detection approaches a method called ionospheric radar; this consisted of observing the disturbance in the ionosphere caused by the deposition of soft x-rays emitted by the exploding device which in turn would modify the reflection of radiowaves from the ground. The Soviets did not explain why they objected to this method, but it became clear that they were concerned that ionospheric radars could also detect missile traversals through the ionosphere. In a private session with Federov, I maintained that we were to assess the narrow issue of monitoring nuclear explosions while Federov replied, "I am to take all factors into account," -- so much for the separation of scientifically relevant facts from political or strategic considerations. We then agreed to disagree on this point.

Notwithstanding some of these inherent tensions, the scientific delegation to the Conference of Experts, TWG-I and TWG-II, produced serious reports which broadly outlined the state of knowledge of detection and identification of nuclear weapons tests at that time. The rest is history. When the negotiations continued on the political level, disagreement persisted between the U.S. and Soviet sides on the number of on-site inspections which could be triggered by suspicious events. These disagreements frustrated the strongly expressed hopes of President Eisenhower and Hans Bethe to achieve a complete cessation of nuclear tests. On his departure from office President Eisenhower stated that failure to achieve such cessation was one of the great disappointments of his presidency.

Hans Bethe lived long enough to see a progression of agreements limiting nuclear test explosions: the 1963 Limited Test Ban Treaty which ruled out all nuclear explosions other than those underground; the 1974 Treaties limiting the yield of underground explosions to 150 kilotons and forbidding so-called peaceful nuclear test explosions. Finally, the Comprehensive Test Ban Treaty was signed by 160 countries. The United States was the first to sign in 1996, but has not as yet ratified the treaty. Therefore, the treaty is not yet in force because ratification of all states having potential capability to produce nuclear weapons is required. Nevertheless, all states have obeyed a nuclear test moratorium after 1998 when India and Pakistan conducted their tests. No predictions are possible today whether, after over 2,000 nuclear test explosions, such tests will ever resume. Even more important, no one can be sure today whether nuclear weapons will ever be used in hostilities again since 1945 when two American bombs extinguished the lives of a quarter of a million people in Hiroshima and Nagasaki.

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Hans Bethe and Societal Issues

Edwin E. Salpeter

A whole issue of *Physics Today* will be devoted to Hans Bethe, so here I will only touch on his Physics and Society impact. My reminiscences, although largely from Cornell, go back almost 60 years. I will mention some of his subtler but nevertheless very influential achievements.

Hans A. Bethe was born in 1906 in Strasbourg, when it was part of Germany, and then moved to Frankfurt with his parents. His father, a professor of Physiology, was Protestant and his mother was Jewish. Hans was a promising theoretical physicist already in his twenties and had already worked with Enrico Fermi in Rome before leaving Germany permanently in 1933 because of the Nazi Race Laws.

After two years in England he came to Cornell, where he launched the Physics Department into the top rank. In 1936/37 he wrote (partly with co-authors) the "Bethe Bible" on essentially all that was known about nuclear physics then. In the following two years he worked out how stars generate energy by converting hydrogen into helium and the Nobel Prize came in 1967. During the war he became the Head of the Theoretical Division for the Los Alamos Manhattan Project, which built the first fission nuclear bomb. He was masterful not only in the work he did himself but in stimulating diverse brilliant physicists under him into a coherent output.

Soon after the war Bethe got involved in public policy issues, much of the time on the opposite side to Edward Teller, despite their similar European backgrounds. Although Bethe lost a few important battles, such as the building of the hydrogen bomb and the removal of J. R. Oppenheimer's security clearance, admiration for his unwavering strength of character and defense of life grew. His pronouncements against the hydrogen bomb helped to alert the general public against the utterly insane weapons build-up during the cold war and the eventual decrease of the nuclear weapons arsenal is to his credit. His enormous prestige on policy issues was partly explained by his statement, "I am a Dove--but I am a TOUGH Dove," as he continued to work on technical military matters. The Limited Test Ban Treaty in 1963, and the more comprehensive one in 1996 (the latter not yet ratified) were substantial achievements.

Bethe helped to debunk the Anti Ballistic Missile defense system in three different periods: First under Presidents Johnson and Nixon, then under President Reagan with his "Star Wars" initiative, and now under President Bush with the Boost Phase plans. For each of the three initiatives Hans encouraged his younger colleagues to undertake detailed investigations, which showed that these initiatives are doomed to failure.

On most public policy issues Hans Bethe is on the side of moderate liberal scientists, such as members of the Union of Concerned Scientists. However, his attitude in favor of further nuclear fission power plants, as the lesser of two evils, is the one exception. He has given detailed technical arguments that the safety issues for a working reactor are not so severe, but this is one of few cases where he has "shown his age" over the last few decades. The main fears and dilemmas have switched from in-use reactors (in spite of Chernobyl) to the decommissioning and then the disposal of nuclear waste. Bethe has not had much input into these worries.

Hans had a subtler but important influence on his younger colleagues and on University administrators, both by teaching them directly and by being a role-model for sensible attitudes. I found that out already as a young graduate student in England 58 years ago when Hans would visit and go from one student to the next (like a chess master playing multiple boards), giving advice not only on physics itself but on questions about their future. He had a strong influence on Cornell University presidents and their staff on the principle of not allowing any classified work to be carried out on campus. Hans, of course, continued to work on classified matters and it was of considerable inconvenience to him to not have classified facilities nearby and yet he insisted on this. His example was not lost on Cornell and this principle has been kept all these decades and has been quietly passed on to some other universities. Again, in the Joe McCarthy era Hans quietly strengthened Cornell's resolve to shield local victims of the McCarthy witch hunts.

Hans Bethe was a thoroughly happy man both in science and life, but he told me that the slow drift towards fascism in the present U.S. administration left him very frustrated. Just when speaking-out against belligerent horrors and loss of civil liberties became particularly important, he felt that he was no longer listened to and so he did not speak. Worse, his younger colleagues were not speaking out as he had done at their age. Some of the Fascist parallels just cannot be appreciated fully by "youngsters" in their seventies and eighties, like myself. Unlike us, Hans was there in the Weimar Republic where citizens were not against democracy but just did not want to make waves. Unlike us, he was in Rome in the early Mussolini days during preparations for an attack on Abyssinia. The parallels between Iraq

now and the occupation of Abyssinia then are particularly frightening: The occupation went quickly and easily but the understandable resentment of the Abyssinian populace led to troubles for Italian soldiers for many years and caused Mussolini to tell more lies.

We all revere the memory of Hans Bethe, and I hope that we will show it by clearly and forcefully speaking out now on the side of humanity.

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Hans Bethe - Last of the giants *Sidney Drell*

Hans Bethe was the last of the giants of modern quantum and nuclear physics. He was present at its creation and for more than seven decades contributed enormously to deepening our understanding of the physical nature of the earth and the stars. Beyond his major contributions to advances in modern science and to the development of the atom bomb, he became an important and actively engaged leader among scientists who felt the responsibility of our community to help governments and societies understand the potential impact of these achievements on the human condition. To this end he contributed prodigiously throughout most of his life. As a government adviser at the highest levels and a participant in public forums he strove to ensure that consequences of scientific and technical advances – particularly in nuclear weapons and energy – were utilized toward peaceful and beneficial purposes.

I had the personal privilege of working with Hans for more than four decades on government committees concerned with nuclear weapons and arms control. Hans gave unstintingly of his enormous scientific talents to help the United States government make wise policy choices when it came to building a safe and reliable nuclear deterrent, to negotiating and verifying arms control treaties, and to understanding technical limits on complex systems. The batting average in activities of this type, measured by the ratio of successes in moving the policy decisions in the desired – and of course the correct – directions is not as high as one would hope. This, however, never discouraged Hans. He would just work harder the next time. I recall, in particular, our many sessions together in Washington and at the weapons labs trying to clarify the physical limits of potential ballistic missile defense systems, including exotic new concepts in the so-called Star Wars program during the 1980's.

Hans always approached problems with an objective view based upon deep and sound scientific knowledge, which was the foundation of all his policy recommendations as well as his great scientific contributions. He was exemplary in shielding scientific facts from personal opinions or prejudices. This made his advice to governments and his public testimony uniquely valuable.

Perhaps Viki Weisskopf gave us the best description of Hans Bethe in 1995, during a celebration of Hans's 60th anniversary as a professor at Cornell University, when he characterized him as a "dreadnaught" plowing straight ahead with irresistible force to achieve his scientific, technical, and policy goals. He was a giant in his time. We are all going to miss him.

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COMMENTARY

Report on POPA Meeting of January 9, 2005

Barbara Goss Levi

The APS Panel on Public Affairs continues to deal with a wide range of issues. Below are some of the issues that occupied the panel at its January meeting:

Revision of APS Statement

POPA reviewed existing APS public statements, which date back to 1981, to consider which have been superseded by later statements or overtaken by events and which may warrant revision. POPA decided to retire a number of them. It is consulting with the Committee on the Freedom of Scientists to consider issuing a more generic form of two statements that dealt with human rights of scientists in specific countries. POPA also decided to revise a statement on creationism, and to consider updating statements on the US helium reserve and on the possible health effects of power line fields. All retired APS public statements will remain on the APS website.

Export Control

POPA approved a letter to be sent to Secretary of Commerce Evans regarding export control. The letter expresses the concern of APS about recently proposed changes that would require a university or national laboratory to get a license before they could allow a foreign national faculty member, staff member or student to use export-controlled scientific equipment.

Fraud Allegation at MIT's Lincoln Lab

POPA discussed a recent issue at Lincoln Lab, the lab that MIT operates for the government. The issue involves an allegation that two scientists at Lincoln Lab behaved improperly in reviewing tests from the missile defense program. MIT's attempt to investigate the allegations was stymied when the defense department classified the relevant data and declared that, because of previous federal reviews of the issue, a committee with the necessary clearances, which MIT had established to review the matter, had no "need to know that data." POPA debated whether to get involved in this issue and in what way. One option was to look more broadly into the question of government-owned but university-operated laboratories. Another option involves finding out whether there is enough data already in the public domain to investigate the issues. By a narrow vote, POPA chose the latter option. A subcommittee is to report back to POPA for further possible action.

Science Advice to Congress

A subcommittee of POPA reported on three items concerned with enhancing science advice to government. One was the recommendation that the APS issue a statement supporting efforts to enhance the capabilities of Congressional support organization to carry out technically-based studies of policy options. POPA approved a statement that will go before the APS Council for approval in April.

The second proposed action was for APS to work with the recently established AAAS Center for Science, Technology and Security Policy, headed by former State Department science advisor, Norman Neuriter. The idea would be for the Center to help assemble science and engineering society representatives to meet with congressional staff several times a year. Among the activities would be discussions of questions pending in Congress or sharing of information about ongoing science advice activities at the societies. The POPA subcommittee on Science Advice will continue to explore such collaboration with AAAS.

The subcommittee also proposed a possible mechanism for coming up with suggestions of topics worthy of greater exploration by POPA. POPA decided to form a subcommittee on study topics, to report back at the next meeting.

Nuclear Energy Study Group

POPA has a nuclear energy study group, which is examining how nuclear energy can be made more proliferation resistant. The study group and government nuclear experts met in mid-December 2004 and presented the outline of a report. They will continue to work on this vital topic.

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Thoughts on reading about the life of Theodore Taylor

Jeffrey Marque

The January/February 2005 issue of *Bulletin of the Atomic Scientists* (Volume 61, No. 1) has an obituary for Theodore Taylor, who died in October 2004. I knew nothing about Taylor before reading this very short piece in the Bulletin, but his story strongly impelled me to write this piece.

According to the *Bulletin* article, Taylor started making smaller and smaller designs for fission bombs in 1949 at Los Alamos, with great success. He gave his creations names such as “Scorpion”, “Wasp”, “Viper”, etc, with miniaturization culminating in his “Davy Crockett” weighing in at a mere 51 pounds. Taylor was obsessed with his work, poring over aerial photographs of target Moscow on the day of the birth of his second daughter. He drew circles of destruction from a 500-kiloton burst over Red Square on these photographs, and he once wrote in an earlier edition of the Bulletin, “I remember feeling disappointed because none of the circles included all of Moscow.” At some point, Taylor apparently swore off weapons work, and he subsequently visited Red Square. There, he cried at the thought that he had wanted to annihilate the place. He wrote, “Yes, my work at Los Alamos had been so intellectually stimulating, so compelling, but so insane.” According to the January/February 2005 issue of the *Bulletin*, “Taylor dedicated the remainder of his life to hastening arms control and denouncing all things nuclear.”

What is the nature of the “insanity” that Taylor claims gripped him during his weapons work? Throughout the world, there are many thousands of people working on the design of weapons of mass destruction (WMD), and mankind consequently hovers at the brink of self-destruction. Any effort to enhance the security of our species against the threat of WMD is, in my view, insufficient if it does not include an effort to understand the individual and group psychology of the many people who, like Taylor, are obsessed with their technically fascinating work on WMD development. How can we make inroads to enhanced security from WMD if we do not understand the powerful psychological forces that drive people to create such weapons? So many people who worked at Los Alamos during the Second World War have remarked on how much fun they had working on the bomb, and on the intense pleasure that they had interacting with others during the pursuit of their goal. We need to understand the origin of that pleasure and fun if we are ever to gain any control over its role in WMD genesis.

I am not personally aware of studies concerning the topic of the psychology and organizational dynamics of people involved in WMD development, but I am sure that the *Forum on Physics and Society* (P&S) would be a superb venue for the dissemination, and discussion, of such studies. I can think of few subjects that are more important for discussion within P&S, as arms races could probably not exist without the “insanity” mentioned by Taylor. I invite any readers of P&S who are familiar with such studies to write about them in our newsletter.

Taylor is certainly not the first WMD designer to switch from fanatical design effort to trying to save the world from the fruits of those efforts. Oppenheimer and Sakharov are two of the most prominent figures who did the same thing. With all of the discussion now about ethics in science, one wonders if, in our graduate programs, raising the issue of the psychology of weapons work might be appropriate. At the very least, I believe that the presentation of papers on the topic belong in P&S sessions at our APS meetings, and in articles for our newsletter.

The great mathematician Stanislaw Ulam took up teaching at the University of Southern California after completing his role, at Los Alamos, in the Manhattan Project. In his autobiography, Adventures of a Mathematician, Ulam wrote, “At USC I found the academic atmosphere somewhat restricted, rather anticlimactic after the intensity and high level of science at Los Alamos. Everyone was full of good will, even if not terribly interested in ‘research’.” He then describes how he almost died there of encephalitis, of the recovery period from the neurosurgery that saved his life, and of his worries about what mental powers he may have lost on account of the illness. “What comforted me the most was the receipt of an invitation to attend a secret conference in Los Alamos in late April. This became for me a true sign of confidence in my mental recovery. I could not be told on the telephone or by letter what the conference was about...but I guessed correctly that it would be devoted to the problems of thermonuclear bombs.” Ulam soon left USC and returned to Los Alamos where, together with Edward Teller, he invented the hydrogen bomb. Reading Ulam’s autobiography, I have had the chilling thought that, for this brilliant man, living in LA and the mundane teaching of calculus almost killed him, whereas the very challenging work leading to the invention of the hydrogen bomb was his salvation. The locus of invention of the greatest weapons of mass destruction as the site of personal salvation for a great intellect: Can there be a greater irony, or more chilling suggestion of the problem of personal fulfillment (or salvation!) deriving from WMD development?

I believe that it was in Ladislav Farago’s book Aftermath: The Hunt for Martin Bormann that one can see a document from an engineering company in Nazi Germany, called Topf if I recall, giving specifications for ovens at extermination camps. On the bottom of the document is written a comment to the effect: “It is always a pleasure to do business with you.” The “insanity” that Taylor wrote about, and against which he devoted the latter part of his life, certainly did not start with nuclear weapons. It is high time that we at P&S delve into this dark recess of the human mind and do our best to understand it.

Jeffrey Marque is the Senior Staff Physicist at the Palo Alto site of Beckman Coulter Corporation and a co-editor of this newsletter. He thanks Dr. Lynn Eden, of Stanford University’s Center for International Security and Cooperation, for helpful comments, suggestions, and discussion.

LETTERS

A Limit to Growth of Nuclear Fission Power

The fascinating exchange between Garwin and Hannum, Marsh, and Stanford in your January issue, on the subject of the necessity and advisability of nuclear fuel reprocessing, and the following article by Albrecht and Bodansky (AB), on the potential for nuclear energy, all omit to mention the key point that any reader of Vaclav Smil's "Energy at the Crossroads" (nicely reviewed by Cornelius Noack in the same issue) would realize at once: the US has only 5% of the world's population, and the rest of the world has an appetite for energy growing far faster than nuclear fission will ever likely safely accommodate.

Garwin touches on the point in mentioning that "the supply of uranium is no problem" for the world's 300 GWe capacity (though 300 GWe multiplied by 12,000 tons/GWe lifetime requirement does exceed the 3 million ton current-price reserve he mentions) and suggesting that "those interested in expanding nuclear energy ought to [...] support R&D into acquiring uranium from seawater". AB echo this in a brief discussion of 1700-3000 reactors worldwide.

In discussing the potential for nuclear power to displace half of US oil consumption and all US coal, AB see a need for scaling up US reactor numbers by a factor of 6, to 600 GWe capacity. Those numbers may actually be low if the oil-replacement is supposed to be hydrogen, given energy losses in electrolysis or thermochemical production. But extended to the rest of the world 600 GWe becomes 2400 GWe if the US retains its 25% share of global energy use at roughly 2000 levels, or more likely 5000-10000 GWe or more by mid-century, as globalization extends its equalizing influence. Have any of the authors seriously considered the likely side-effects of a world with on the order of 10,000 1GWe fission reactors?

For one thing such a world would consume 2 million tons of uranium annually in the once-through cycle; the 20-200 million tons available without ocean processing suddenly seems much more limiting. The emphasis on reprocessing and breeder reactors by some of the authors is justifiable in this context - but the question really is, as suggested by Garwin's emphasis on terrorism and malfeasance, would such a world long remain inhabitable?

AB claim that "no restraints on nuclear power in 'peaceful' countries can prevent weapons development elsewhere". This misses the fundamental point that a lack of affordable energy alternatives in other nations justifies their construction of fission reactors for civilian use, and the step from a peaceful nuclear program to weapons is not large. If the US does not lead in R&D on affordable alternatives, and we have been derelict in this now for over 20years, much of the rest of the world will see nuclear as the only option, as for example China is now doing in planning for dozens of new fission reactors.

Perhaps there is a danger, as AB suggest, that "the opportunities offered by nuclear energy will be inadequately exploited" - but nuclear power has long had advocates at the highest levels of US government, and the 2006 budget proposal(1) includes \$1.1 billion over seven years for the "Nuclear Power 2010" initiative, with a total of \$100 million for that program and "Generation IV" nuclear plant design in the 2006 budget year. This is probably a good thing; in an ideal world, each of the likely components of large-scale energy supply (nuclear fission, fusion, solar PV, bio-fuels, and storage/transmission improvements) would receive \$1 - \$2 billion/year in advanced research and development funding, in the US. But fission is far from being the only answer, and it should not be pursued at the expense of alternatives that promise a cleaner, safer, and more scalable solution to world energy needs.

Physicists' affection for nuclear energy runs deep, but there are plenty of exciting things (applications of superconductivity and nanotechnology for instance) for physicists to work on in

photovoltaics, energy storage and transmission, and even bio-energy alternatives. Solar photovoltaics have seen sales expanding at over 30% per year recently, despite continued high prices for the materials; in another decade that would provide the capacity of several new fission plants every year; wind power is already close to that level. Nuclear energy will continue to be needed as a component of world energy supply, maybe even expanded somewhat, but let's focus our efforts on the truly revolutionary options coming along.

(1) FY 2006 Budget documents are available online:

<http://www.whitehouse.gov/omb/budget/fy2006/>

For the Department of Energy summary, including nuclear programs:

<http://www.whitehouse.gov/omb/budget/fy2006/energy.html>

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There is no such thing as a proliferation-proof fuel cycle.

Thanks very much for sending me the January 2005 copy of Physics and Society. It is a very informative issue. One comment on the exchange between Dick Garwin and the Argonne group supporting pyro-processing: There is no such thing as a proliferation-proof nuclear fuel cycle; this point tends to be submerged in the detailed exchange of views. All nuclear fuel cycles differ in the amount of effort required for safeguarding in terms of money, manpower, and technological tools, but that amount is never zero.

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Response to Arthur Smith's Letter

Before responding to Arthur Smith's letter, we should call attention to the footnotes to our article (P&S, Jan. 2005). These were too extensive to include in the printed version but they appear in the web version.² Unfortunately the note indicating these footnotes was omitted from the printed version, as were the references to them beyond that for footnote 5. [Editor's Note: We apologize for the inadvertent dropping of many of the references intended for the web edition. We are currently attempting to re-insert them into the archived January edition and suggest that readers look for them there.]

Dr. Smith is correct in pointing out that the U.S. has only a small share of the world's population. But we consume a much larger share of the world's fossil fuels. Thus, reducing fossil fuel use in the U.S. alone would be a big help---not only in easing our own burden of oil imports but globally by easing the competition for oil and reducing CO₂ emissions.

Although our article focused for specificity on the United States, nuclear expansion should proceed elsewhere. Countries that already have nuclear power account for over 60% of the world's population and almost 80% of the world's energy consumption (as of 2002 data). Their increased use of nuclear power would give similar national and global benefits as gained from U.S. use.

We do not expect the needed future energy supplies to come from nuclear energy alone. Our

² See: <http://www.aps.org/units/fps/newsletters/2005/january/articles.cfm#bodansky>

hypothesized U.S. target of 600 GWe of new nuclear capacity by 2055 covered substitution for coal and (some of the) oil and the replacement of aging existing reactors. The target did not take account of other increases in electricity demand or the role of non-nuclear energy sources. These obviously will have to be major contributors. [The magnitude of the nuclear requirement was discussed in footnotes 4-10; the possibility of achieving this expansion was discussed in footnote 26.] Global nuclear usage was not addressed, aside from a brief reference to uranium supplies. However, one of us (DB) has discussed, as an illustrative target, a global total of 3000 GWe in 2050, with nuclear sources supplying something like half of the world's electricity.³

We are mindful of the proliferation risks to which Dr. Smith alludes, but as discussed in our original letter we think that any incremental proliferation risks are outweighed by the risks posed by oil dependence and accelerated global warming.

Of course, any capacity estimates, for some 45 or 50 years hence, are highly speculative and useful only for purposes of crude orientation. The outcome in 50 years will be determined by a variety of technological, economic, and political factors that can be only dimly perceived now. The probably optimistic targets cited above define a direction in which to proceed, not definite milestones that we expect to be reached on schedule.

We fail to understand the “fundamental point” that Dr. Smith makes connecting nuclear fission, nuclear weapons, and a lack of affordable alternative energy sources. If nuclear power in the United States, and in other developed countries, frees fossil fuels to use elsewhere, it would lessen, not increase the “justification for their construction of fission reactors.” As to China, we applaud its pursuit of nuclear power. Every new reactor in practice replaces a much more damaging coal-burning plant. Of course, for China there is no issue of weapons proliferation because it developed weapons long before developing nuclear power.

We concur in Dr. Smith's view that the U.S. should also play a leading role in the development of alternative sources---which we interpret as meaning renewable sources---but see no conflict between an ambitious nuclear program and an ambitious renewables program. It may be a zero-sum game at some future time, but with federal appropriations for both of these programs now at a regrettably low level, it is far too soon to pit these complementary approaches against each other.

Thus, we agree that far more should be spent on all promising energy sources, including nuclear fission, renewables, and “carbon-free” coal. We obviously disagree on the relative promise of these potential contributors, but are content to let time determine the appropriate role for each. This determination can be properly made only if these avenues are all vigorously pursued.

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Nuclear Power Know-how is Here and should be Used

Dr. Smith notes that expanded deployment of nuclear power is desirable, but then he argues that nuclear power initiatives "should not be pursued at the expense of alternatives to cleaner, safer, and

³ David Bodansky, *Nuclear Energy: Principles, Practices, and Prospects*, 2nd edition (Springer, 2004), Ch. 20.

more scalable solutions to the world energy needs." He appears to suggest that solar, bio-energy, and wind are viable alternatives to large scale deployment of nuclear energy.

But none of those alternatives is "scalable" the way nuclear power is. Each of them surely has a role to play, and each is receiving significant federal funding, but they cannot supply the bulk of the energy needed for a healthy and dignified life in the developing world. Artificially restricting the growth of nuclear power would severely limit per capita energy consumption -- a condemnation to continued poverty.

Dr. Smith asks, "Have any of the authors seriously considered the likely side-effects of a world with on the order of 10,000 1-GWe fission reactors? . . . would such a world long remain inhabitable?" We would turn the question around, and suggest that he do some serious calculating. He should look at the side effects of a world *not* making large-scale use of nuclear power. He needs to consider the vast expanses of real estate that would be preempted for massive solar power and wind power, the backup energy systems needed for times when the wind doesn't blow and the sun doesn't shine, life-cycle costs, and the environmental consequences of trying to make up the overall shortfall by burning coal at many times the current rate. His quantitative case has not been made.

With regard to a world dependent on nuclear energy, he says, "For one thing such a world would consume 2 million tons of uranium annually in the once-through cycle. . . ." That's an eventuality that is not in the picture, of course. The idea that it would be economical to try to meet the world's long-term energy needs with the throw-away, once-through cycle -- which extracts well under a hundredth of the energy in the mined uranium, and leaves troublesome by products -- is preposterous.

He also comments that "the world has an appetite for energy growing far faster than nuclear fission will ever likely safely accommodate." Perhaps the global energy appetite is indeed insatiable, but that does not excuse us from doing whatever we can to meet it. The major point of our initial article was that for nuclear power to replace fossil energy as the dominant supplier of the world's long-term energy needs, an effective, proliferation-resistant recycle technology will be needed -- such as the combination of fast reactors and pyrometallurgical recycling. That technology can tap a safe, truly sustainable, inexhaustible source of energy in quantity that is beyond the reach of the other renewable candidates.

Dr. Smith remarks that "a lack of affordable energy alternatives in other nations justifies their construction of fission reactors for civilian use, and the step from a peaceful nuclear program to weapons is not large. . . ." He is correct, of course, on both counts, which is why we all stress that judicious management of the nuclear cycle is mandatory. A realistic goal is a safeguarded fast-reactor economy that limits the global inventory of plutonium to what is in service at power plants.

Political realities aside, in theory, it is possible for developing nations to have the benefits of nuclear power without the need for sophistication in nuclear technology. H. Feiveson describes a concept "that holds promise of being proliferation-resistant in a nuclear world 10-20 times expanded from today is the . . . hub-spoke arrangement where all sensitive activities are performed at a central, perhaps international, facility, with sealed nuclear reactors . . . then sent out from the central facility to the 'client' states." [1] An example is the exceptionally small, 10 megawatt "nuclear battery" that can run for perhaps thirty years without refueling being proposed by Toshiba for the town of Galena, Alaska. Other models could supply up to several hundred megawatts of electric power.

A world with adequate supplies of energy and fresh water is vital for international stability. Nuclear know-how is here to stay, and it offers an affordable way to obtain adequate quantities of both of those commodities -- a vital contribution to reduction of tension between nations. It is stability, not lack of reactors, that is necessary to prevent nuclear conflict.

[1] Harold Feiveson, "The Search for Proliferation-Resistant Nuclear Power." FAS Public Interest Report, Volume 54, Number 5, September/October 2001. On the Web at <<http://www.fas.org/faspir/2001/v54n5/nuclear.htm>> <<http://www.fas.org/faspir/2001/v54n5/nuclear.htm>>

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William H. Hannum has been a senior official with the Department of Energy; Gerald E. Marsh, retired from Argonne National Laboratory, is a physicist who served with the U.S. START delegation and was a consultant to the Office of the Chief of Naval Operations on strategic nuclear policy and technology for many years; George S. Stanford is a nuclear reactor physicist, now retired from Argonne National Laboratory after a career of experimental work pertaining to power-reactor safety.

Weaponizability of Degraded Plutonium

The 1962 test was advertised to prove experimentally that reactor-degraded plutonium could be used for military-quality weapons. I do not believe that reactor-degraded plutonium is suitable to substitute in warheads designed with weapons-grade plutonium (or uranium, for that matter.)⁴

This is how I would restate the Hannum, Marsh and Stanford⁵ case:

...weapons made from reactor-grade plutonium have a yield that is highly [somewhat] unpredictable — they would be very likely to “fizzle,” producing no mushroom cloud at all [might “fizzle”]. Thus their usefulness as a military weapon is questionable [extremely unlikely] to say the least, and even as a terrorist weapon that will definitely [has a good chance of being a] fizzle, they are technically beyond the reach of subnational terrorist organizations.

We probably all agree that plutonium categorized as reactor-grade should be accorded high-level intrinsic, procedural, and technical safeguards, just as all other plutonium. It's too bad the second Volume of *Nuclear Shadowboxing* had not been published, because it contains a far-more detailed update and analysis of this persisting issue.⁶

Anyway, since we lack evidence that reactor-degraded plutonium has the same proliferation risk as weapons plutonium, I don't think we want to appear too cavalier. The canard about equal risk for all grades of plutonium is amply addressed in *Nuclear Shadowboxing*. Suffice it so say here: Evidence to support a position that fails to discriminate between grades of plutonium is under daily onslaught as additional nations proliferate nuclear weapons, evidently confining themselves to weapons-grade plutonium and uranium.

Of the half-dozen or so nations known to have gotten close to the weaponization threshold, none chose reactor-degraded plutonium. Some readers might not realize that the longer it is left in the reactor after the initial creation of isotope 239, the poorer the plutonium quality gets. Light-water power-reactor burnup utterly destroys the weapons-grade utility of plutonium, no matter how you sugarcoat it.

The tally to date is as follows: the United States, Soviet Union, United Kingdom, France, China, India, and Pakistan (the acknowledged nuclear-weapon states) made all of their weapons strictly from weapons-grade fissile materials. Threshold states — e.g., Israel, South Africa, Sweden, Switzerland, Iran, South Korea, and Iraq — have flirted only with weapons-grade materials. After more 60 years of nuclearization, that's a score of about 14 to 0 in favor of weapons-grade vs. reactor-grade. How would you explain that away?

⁴ A. De Volpe, "A cover-up of Nuclear Test Information?", *Physics and Society*, Vol **25**, No.4. (October 1996).

⁵ W.H. Hannum, G. E. Marsh, and G. S. Stanford, "Purex and Pyro are Not the Same," *Physics and Society*, (July, 2004).

⁶⁶ A. De Volpe, V.Minkov, V. Simonenko, G.S.Stanford, *Nuclear Shadowboxing* (volume 1, *Cold War Redux*, was published in December 2004 [www.NuclearShadowboxing.info], and Volume 2, *Legacies and Challenges*, is due out by this summer.)

Nor is the physics or engineering of reactor-degrade plutonium very promising. Moreover, the experimental results (of the 1962 test) are kept from the public, Can you see why there are skeptics among us?

Sure, terrorists might dream of getting their hands on nuclear or radioactive material, and certainly it should be tightly protected at least as well as gold bullion. But let's not go overboard.

Like many fine wines, plutonium left too long in the confines of a hot reactor will turn vinegary, too sour for military quality weapons.

The legendary capabilities of weapons-grade plutonium are unassailable, but what defies public physics and engineering is the overhyped status accorded to reactor-degraded plutonium (*aka* reactor-grade plutonium). Just as all nuclear materials must be fully safeguarded, it does not serve the cause of nonproliferation, nuclear safeguards, or counter-terrorism to let policymakers and the public be led astray by vastly overhyped claims about weaponizability of reactor-degraded plutonium.

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Time for a New Paradigm

I have followed the material fighting against all the forms of creationism, with interest, cheering them on, until Alvin Saperstein's Commentary on the Two Brains (where his A student in Astronomy asked after the course if the Earth wasn't just 5000 years old, as she had been taught in church). This made me finally face up to the fact that exposure to scientific facts have little effect on beliefs. And our effort to stem the still active tide of imposing irrational beliefs on our children will not be stopped by correct knowledge alone. We need a new paradigm.

The battle for our minds between measurement-based science and faith-based religion cannot be settled since the two realms scarcely overlap. On the other hand the source of any set of beliefs is today easily accessible to scientific inquiry. This is a result of the remarkable discoveries that science has made on how our brains function. I believe that physicists, in particular, being so focused on the external world, have overlooked the results of brain function research with respect to its implication on what is real and what is imagined.

One of our own, Francis Crick, made great advances in this field, and his book *The Amazing Hypothesis* lays out the functioning of the brain's visual system in great detail. We all know that there is no projection screen in our brains, so just how does the brain reconstruct for us a sensation that we are seeing the real world out there? An interesting physics question. Crick himself was convinced that all the sensations we ascribe to our minds have "neural conjugates" that is, specific neural bundles where this sensation is generated.

One specific case is that of color. All of my friends and even some physicists have trouble with the statement that "the color is not on the object it is in the mind". Color is very *real* to all of us, yet it is not a property of the physical world. What is a property of the physical world is the reflected spectrum, which we can measure accurately with an external instrument, so it must be really real. What the brain does for us, which is of tremendous importance to our being, is to convert this spectrum into the sensation of color. Thus the color exists only in the mind. One can say it is *imagined*.

Backing up, evolutionists show us that what really set our species apart were changes in the brain structure, not body structure. All animals have emotions and instincts, more complex animals have consciousness, reasoning, remembering, thinking and various levels of *intelligence*. We may have a superior level of "intelligence," called symbolic, linked perhaps to one thing no other animal brain has - a language capability. There is no question that this capability takes us far beyond animal communication to the accumulated, shared, store of knowledge, which we call culture. This is why

education is so important in maintaining our way of life. This knowledge base is not built in. And when it is distorted, it changes us, because we are what is in our minds.

There is another brain sensation that we all have, whose reality is questionable, like color, and which dominates our belief systems. That is the sensation of being aware of ourselves, sometimes called self-consciousness. We perceive that we exist beyond our mere bodies. This is tremendously important to us, like color. The *self* becomes the important thing. And security of this self becomes the dominant factor in our behavior. Death has meaning for us, as it does *not* for any other species, because we come to wonder if the self survives. We also come to wonder what we are doing here. We wonder what this is all about. But most immediately, quite naturally, knowing death, we wonder if we are secure.

Whether the self is imaginary or not, this sensation had, has, terrific consequences. It drives us to use our intelligence to search for security (would we use our intelligence just because we had it? This is a point evolutionists make about how latent features come to the fore). And it made us hope that life everlasting exists. But if it did, where does it exist, who arranges all these things, who is in control so we are safe, who am I really?

Lacking science technique, the early members of our species, who had the same brain we have, and language skills, made up explanatory stories, invented gods and religions, to satisfy this need to know. This calmed the fears aroused by being self-conscious, fears stirred up by becoming aware of themselves, awakening in a strange and unknown universe.

Does an active God exist who cares for us, who created all this, recently or long ago, or not at all, is a matter of individual faith. *What is clear is how that faith originated.*

The critical belief is whether one believes in life after death. For me, the self is just a brain sensation which drove us to become human, and when my brain ceases to function, my soul, my personal consciousness, vanishes. For me, the exciting thing is, even though by accident, I know that I am alive, and that the only way to keep this happy experience going is to make sure the human species survives, which requires all of us to work to that end. We should keep reaching for the stars.

If one believes in a life after death, then there has to be a heaven, that is, some place to go, supervised by good super natural beings, and a hell, if a judgment is involved, supervised by bad super beings. The collection of stories that lay this all out in rich detail are the evolved religions, which satisfy the need for security and explanation..

Certain stories are more dangerous to our survival than others. One way to fight their acceptance is to point out the source of the beliefs.

For my friends in organized religions, God bless. For my other friends, you are already blessed.

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REVIEWS

Population and its Discontents, special issue of WorldWatch magazine, Sep/Oct 2004.

This review is being run simultaneously in *Physics and Society* and *The Teacher's Clearinghouse Newsletter*, with permission from both publications.

I suspect that many readers of *The Teacher's Clearinghouse Newsletter* are fans of WorldWatch magazine, published bi-monthly by the Worldwatch Institute. The Institute also publishes several annual items, including *State of the World* and *Vital Signs*. The Institute's work revolves around the transition to an environmentally sustainable and socially just society, and how to achieve it. The magazine appears to be an excellent teaching tool. I recommend it for high school libraries and classrooms, and for all general and university libraries.

Nearly this entire issue is given over to a sampling of 11 articles on several population topics, yet, as the Editor's Introduction states, even at an expanded 60 pages "this issue will be inadequate." Authors include Worldwatch Institute researchers, demographers, university scientists, authors of books on population topics, and economists.

The lead article, "The Population Story...So Far," recounts the history of how we came to be 6.4 billion strong, and demographic challenges today. The UN mid-range estimate says we will number about 9 billion by 2050, and then shrink over the next century. Growth will come from the world's 48 least-developed nations, whose populations could triple by 2050, and from one developed nation: the USA. A major contributor to this unwanted growth is the suppression of women's rights and voices: Girls who marry young, often as young as 8 or 9, early childbearing (a leading cause of death for young women in developing countries), the AIDS assault on women (in 2003 women's rate of infection for the first time equaled men's), illiteracy (two-thirds of the world's illiterates are women), and the constraint, even in the USA, of women's reproductive rights--a constraint that is furthered by the USA's "global gag rule" tying population assistance to a taboo on any discussion of abortion.

"The Hazards of Youth" looks at 100 countries where people are getting not only more numerous, but younger. "Youth bulges" burden these countries with violence and unrest. Tensions in the Middle East, where 65% of the population is under 25, are partly due to the unmet expectations of skilled youth, especially those raised in oil-rich nations where many young people receive good educations but then have little opportunity to use their skills. They then face three paths: migrate to the West, join fundamentalist groups, or enlist in guerrilla groups. The link between youth and violence is strong: Researchers find that nations in which young adults make up more than 40% of all adults were two-and-a-half times as likely as other nations to experience civil conflict during the 1990s.

"World Population, Agriculture, and Malnutrition," by noted scholar David Pimentel and Anne Wilson, notes that 3 billion people worldwide are already undernourished, increases of per-acre food production have not kept pace with population increases, the planet has virtually no more arable land or fresh water to spare, per-capita cropland has fallen by more than half since 1960, and per-capita grain production has been falling worldwide for 20 years.. The article studies the availability of cropland, water, and energy in some detail.

In "A Neo-Malthusian Looks at Fossil Fuels and Fertility," Virginia Deane Abernethy argues the unusual thesis that parents have fewer children if they anticipate hard times ahead, and hence the coming global oil scarcity could result in population growing less than the UN expects. She discusses four examples (Rwanda, Brazil, Egypt, Morocco) that she believes support her thesis, but doesn't mention several obvious counterexamples where economic expectations are low but birthrates are high (Pakistan, Congo, Ethiopia, Niger), and where economic expectations are relatively high but birthrates are low (most European nations).

"A generation comes of Age Under China's One-Child Policy" notes that without the 25-year-old one-child policy, China's population would now be 1.6 billion instead of 1.3 billion, and the population would finally stabilize at well above the 1.6 billion at which the country hopes to stabilize its population around 2050. Implementation of the policy varies, with rural peasant families offering the most opposition and generally granted the option of having a second child without penalty, and with urban couples willingly limiting themselves to one child. In Beijing and elsewhere, a second child is considered an expensive luxury for many middle-class couples. In some areas, implementation has been accompanied by heavy sanctions for non-compliance, including doubled health insurance costs and long-term income deductions and even forced abortions and sterilizations. During the past decade, China's policy has evolved away from such coercive measures and toward voluntary family planning, improved sex education, and health care. A chief criticism has been the implications of an aging society for old-age welfare support; it is a problem common to all aging societies, including Europe and the USA. Another concern is that the one-child policy and preference for males has widened the male-female ratio to 117:100 in 2000; interestingly, several rich Middle Eastern nations have even higher ratios, reaching as high as 186:100.

Well-known economist Herman Daly, author of "Beyond Growth" and other books advocating that economics take account of Earth's "natural capital," writes here on "Population, Migration, and Globalization." He argues that globalization and internationalization are totally different concepts of world development. Internationalization involves a desirable cooperation among stable nations, while globalization involves not only the free mobility of capital and goods but also, in effect, the uncontrolled migration of vast labor pools from regions of rapid population growth with tragic impacts on national economies. Few demographers have noticed that the current flow of goods and capital are equivalent to a free flow of labor and are driven by the same economic forces that would determine labor migration, if labor were free to migrate. The result is a "race to the bottom" that reduces wages and social standards across countries to the lowest common denominator. Thus globalization leads not to a more cooperative world community but to its opposite: global stresses and strains leading to failed nations and international conflict. Furthermore, "global economic integration and growth, far from bringing a halt to population growth, will be the means by which the consequences of overpopulation in the third world are generalized to the globe as a whole."

Since I've already used too much space, I'll just list the remaining articles: "Population, Family Planning, and the Future of Africa," "Population and Coastal Resources in the Philippines," "The Economic Conundrum of an Aging Population," "Low Fertility and Sustainability" (a calm look at the "problem" of an older-aged society), "The Positive Side of the Older Populations to Come," and "Global Population Reduction: Confronting the Inevitable" (argues for reduction to a global population of 1-3 billion).

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Our Final Hour, by Martin Rees,

Basic Books, New York, 2003, 228 pp., ISBN 0-465-06862-6

"Our Final Hour", authored by eminent physicist-cosmologist Sir Martin Rees (England's Astronomer Royal), discusses various ways in which human civilization, and/or human existence, can be catastrophically impacted or even terminated. One of his conclusions is that "the odds are no better than fifty-fifty that our present civilization will survive to the end of the present century"; if this seems shocking, he opines that those odds are not much less favorable than the odds we had of surviving the second half of the last century without a massive nuclear weapons exchange.

But the “meat” of the book is in the detailed scenarios he describes and analyzes. In a chapter on “technology shock” he speculates about nanotechnology, with computers altering human beings with brain transplants, or creating super-intelligent robots which take over the world and extend their influence to outer space. But he also emphasizes the unpredictability of our rapid scientific advances, citing historic prediction failures like Rutherford’s that there could be no practical application of nuclear energy, and von Neumann’s that there would be no need for more than a few computing machines in the entire country. Moreover, unpredictable social and political developments greatly increase the uncertainty.

In a less speculative chapter on “post-2000 threats”, Rees assesses the use of nuclear weapons by terrorists, and several potential biological weapons: smallpox, engineered viruses which suppress our immunity, bacteria resistant to antibiotics, etc. He tells us that he has outstanding a \$1000 bet that by 2020, there will be an instance of bio-error or bio-terror that will kill a million people. After 2020, he says, manipulations of viruses and cells will become commonplace, and there can be unintended consequences. As one example, self replicating nanomachines could, in a very short time, consume all of the global resources needed for life.

The chapter on “slowing down science” points out approaches to doing that, but thoughtfully suggests some of the problems these actions may cause. A chapter on asteroid or comet impacts on Earth includes an analysis of magnitude of effects versus probability, and considers possible counter-measures. A chapter on “perpetrators and palliatives” treats potentially fatal problems arising from the ability of a single individual to kill millions by utilizing genetics, biotechnology, computer networks, etc. It may be decided that intrusive surveillance, mind-altering drugs, or injected hormones are necessary to control the situation, and the author speculates on their potentially far-reaching consequences. We can’t count on influential people acting rationally: He says that James Watt, the Reagan cabinet member responsible for environment and energy policies, was a religious fanatic who believed the world would soon end so there was no need to protect the environment or conserve energy!

Rees presents lots of science along with substantial imaginative speculation and philosophy. For example, he considers the possibility of an experiment with a high energy accelerator (1) creating a black hole that sucks everything on Earth (and beyond) into it, or (2) reassembling quarks into a “strangelet” which contagiously converts anything it encounters into strange matter, or (3) inducing a phase transition that rips the fabric of space resulting in an ever-expanding bubble of vacuum in which atoms cannot exist. Is this reason enough to refrain from very high energy heavy ion collision experiments? Since there would be no conscious human suffering in such scenarios, would they really be tragedies? Should scientific activities not be undertaken if there is an extremely harmful speculative outcome that is extremely unlikely? He notes that before the atomic bomb, and later the hydrogen bomb, was tested, there was serious concern that the high temperatures generated might induce strongly exothermal nuclear reactions between nitrogen atoms in the air, leading to a chain reaction that rapidly consumes the Earth’s atmosphere.

There is lots of discussion about risks from global warming, super-volcanoes, new diseases, laboratory errors, terrorism, etc. There are chapters on the possibility of extraterrestrial intelligent life, and on the potential for humankind to escape from an inhospitable Earth to survive elsewhere.

“Our Final Hour” is short (188 pages) is very readable, and of utmost interest and importance. Rees is both thoughtful and authoritative in the subjects he treats. I therefore recommend this book highly to scientists and laymen alike.

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Abrupt Climate Change: Inevitable Surprises by the National Research Council, National Academy Press, Washington, D.C., 2002, 230 pp., ISBN 0-309-07434-7, hardcover \$49.95.

In the past few years, a virtual scientific consensus has occurred over the issue of global climate change. Strong scientific evidence indicates that climate change is happening, and that the cause is significantly tied to human actions, namely, the modification of the atmosphere by the addition of greenhouse gases. While most climate modeling studies have focused on a doubled greenhouse gas scenario over the next hundred years, the approach assumes that the Earth responds gradually and smoothly to climate forcing. These models have estimated gradual temperature increases of 1.5 to 4.5 degrees C in a century. However, the study of paleoclimatology provides strong evidence that past climate change has not been gradual or smooth. The mismatch provides the impetus for this National Research Council study, the subtitle "inevitable surprises," and the climate issues discussed in this book.

The material is based on the results of several workshops focused on past evidence of abrupt climate change, mechanisms that cause such change, and related economic, ecological and social impacts. The list of participants includes many of the top scholars and researchers in the field. This final report reflects the authoring committee's judgment after extensive independent review following established NRC guidelines. The book therefore provides a reliable guide to the current knowledge and thinking of the expert scientific community on this topic, and is primarily aimed at policymakers.

The book's contents are divided up into an executive summary, followed by six chapters, including: the definition of abrupt climate change; evidence of past abrupt climate change; processes and mechanisms; global warming as a trigger for abrupt climate change; economic and ecological impacts; and the committee's findings and recommendations. Also included is an extensive list of references (32 pages), and appendices describing the committee, staff, workshops, and participants. An acronym list completes the book. In the center of the book are 8 pages of color photos that describe important studies and results.

Abrupt climate change occurs when a climate system is forced across a threshold, triggering a new climate state. The rate of change is determined by the internal behavior of the climate system and is faster than the cause itself. Practically, there is much evidence that abrupt global climate change has occurred in the past. Indeed, there is good reason to believe that abrupt change is intrinsic to the climate system, both regionally and globally. This view provides a different paradigm of climate change, one that is somewhat distressing, given the greenhouse gas forcing currently being applied to the planet. It also raises a series of questions about our ability to understand and predict such change.

The book examines past evidence of abrupt climate change through study of paleoclimatic proxy data of many types, with particular emphasis on the well-studied Younger Dryas era when sudden temperature changes of up to 8 °C per decade occurred. However, the Holocene era (the last 10,000 years) is also extensively described in terms of floods, droughts, the Little Ice Age, the Medieval Warm Period, and various El Nino/ Southern Oscillation events. A summary of patterns of climate variability observed during the past century of instrumental records is detailed as well. Unfortunately, data is relatively incomplete for parts of the climate system during abrupt climate changes of the past, even over the past 100 years.

The search for mechanisms also suffers from a lack of appropriate data. There are several very different possible explanations of abrupt climate change. These include rapid varying external forcing of the system (for instance, massive sudden discharges of freshwater from disintegrating ice sheets), slow forcing that crosses a threshold leading to rapid system changes

(for instance, collapse of ice dams holding meltwater lakes), and spontaneous climate transitions in a chaotic system. In addition, solar forcing, glacial discharges, clathrate (methane) release, and sea ice changes are also potentially implicated in various past sudden climate changes. The concern today is that rapid greenhouse gas forcing enhances the chances for both abrupt and large changes in climate, regionally and globally.

The three chapters on past climate change, possible mechanisms, and on global warming as a trigger form the scientific heart of the book. This material is not light reading; without considerable background in this area, you will find the discussion both difficult and at times confusing. Part of the confusion emerges from the inherent complexity of climate interactions, and the fact that little is known about the causes of previous abrupt climate changes. Nonetheless, the material is not presented very clearly. This is unfortunate because this is an important book, one that should be understood not only by policymakers and climate scientists, but also by other scientists and, to the extent possible, by the educated lay public. The science could be clearer and the text made more accessible to the non-specialist by adding appendices providing definitions of scientific terms and a brief description of fundamental concepts used in climate science.

Because current ecological and economic assessments of climate change assume gradual climate change, abrupt climate change would probably provide much larger impacts than are currently envisioned. Adaptation to sudden changes will be much more expensive and exceedingly difficult, if not impossible, for certain impact areas and countries. For better estimates of these ecological and economic impacts, abrupt climate change models are required.

The book's recommendations are clear and sound: Develop much greater understanding of abrupt climate change processes by collecting additional paleoclimatic data and improving modeling; develop procedures for getting realistic estimates of the probability of extreme climate events; finally, identify and implement "no regrets" strategies to reduce our vulnerability to sudden climate change. This book sets off a serious alarm. The likelihood of abrupt climate change must be taken much more seriously. Are the policymakers in this country listening?

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