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NEWS OF THE FORUM

Election Results

The election is over. There were 729 on-line votes cast, and 55 paper ballots received. Winners are:

Executive Committee: Philip Taylor, Benn Tannenbaum
Vice-Chair: Don Prosnitz
Chair-Elect: Andrew Post-Zwicker
Sec-Treasurer: Pushpa Bhat

—Marc Sher

Obituary – Mike Casper

The Forum on Physics and Society sadly lost one of its founding fathers, Mike Casper at the age of 68 in Northfield, Minnesota, home to Carleton College. (For the history of the Forum, see *Physics Today*, May 1974, and *Physics and Society*, January 1999). The Forum was founded in the tumultuous times of the early 1970s, and it has continually proven that it can debate the complicated issues with balance. It took vision to understand that physics has large impacts, both good and bad, and that the American Physical Society should examine the larger aspects of these topics. Mike was, first of all, a kind human being that we are proud to have known. He impacted our lives in a very positive way. And he could be a lot of fun as well. To engage Mike in conversation, you should have done your homework, because he carried out thoughtful research on the big physics and society topics of the day. It was Mike's idea to establish the Forum's Szilard and Burton–Forum Awards in 1974. Mike understood that scientists are motivated, not only to discover the truth, but also to be recognized by their peer group. Most of us have experienced the thought that we want our physics colleagues to know what we have discovered in the lab or on paper. This means more to us than telling the story to our parents, who probably don't understand what great work we have done. Physics and society research is usually

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not the fodder of tenure and promotion, but Mike realized that a few carrots can help convince over-worked physicists to examine some of the details of global temperatures, arms race instabilities induced be MIRV and ABM, or free temperature of 5 to 20 degrees from internal heat with R30 walls. There is a long list of accomplishments of good physics applications to society by members of the Forum. Mike was a key founder of a forum that was greatly needed and that continues to be a vibrant force.

Mike obtained his PhD in particle theory at Cornell University in 1966 but soon found that he needed to reach beyond traditional research to the "less-established" areas of physics and society. Mike was indeed a dedicated public interest scientist. Here are some of the things he did during his career, cut too short by illness: Mike established the TACTIC program at the Federation of American Scientists, which set up groups of physicists to lobby their representatives in most of the 435 Congressional Districts. He also organized the FAS Nuclear War Education Project and published its newsletter, *Countdown*. Mike played a large hand in organizing the APS Congressional Fellowship Program, which was then copied by many other scientific societies. Mike initiated the Nuclear War Graphics Project, which created slide sets on nuclear weapons, civil defense, and star wars used by hundreds of activists in their own presentations. He served as Executive Director of the Minnesota Nuclear Weapons Freeze Campaign. Mike ran for Lieutenant Governor of Minnesota in 1978 on an energy conservation platform. Mike was a key advisor to Paul Wellstone in his run for the Senate, and after Wellstone's victory, joined him in the Senate as a policy advisor. Mike co-founded the Science, Technology and Public Policy Program at Carleton. As part of the Program, he worked intensely for six months every year with half a dozen student interns who tackled a problem at the interface between science and society, such as nuclear weapons and disarmament, agriculture, alternate energy and HIV/AIDS policy. In what is probably Mike's most fitting legacy, many of these students were profoundly affected by this work and later went on to careers in public interest science and related fields. Among them is Rush Holt (D-NJ), who credits Mike as a major influence in inspiring him to consider a career in public service.

Mike wrote 3 Books; *Revolutions in Physics* (a Physics for Poets text with Richard Noer), *Powerline* (with Paul Wellstone, concerning the struggles of Minnesota farmers to stop an HV powerline from crossing their land), and *Lost in Washington* (about his disillusioning experiences as a Senate staffer). One of his greatest strengths was that he was willing to leave the confines of academia and work directly with citizens to improve their lives. Mike received the Forum Award in 1984 for promoting public understanding of issues related to nuclear weapons, arms control, and energy. He also was awarded the Minnesota Alliance for Progressive Action's Progressive Activist Award in 2002 for his years of activism and leadership. But, more importantly than his accomplishments, Mike was a good friend, who was visionary, brave and loyal, and he is greatly missed.

Dave Hafemeister, Cal Poly University
dhafemei@calpoly.edu
Joel Weisberg, Carleton College
jweisber@carleton.edu

Statement from Incoming FPS Chair

It has been a pleasure and honor to have served this past year as incoming chair of the FPS. My main role in this regard has been to chair the FPS Program Committee for the March and April meetings. As I also served on the APS task force for the April meeting I was able to promote directly our goal of helping create "thematic" meetings. This year we focused on Energy and Climate Change, and also on Nuclear Proliferation, two topics that I expect will continue to remain high on our list. We are having an "Energy Day" at the April meeting, and two of the plenary speakers at the April meeting, Steve Chu, and Jim Hansen, will be speaking on Energy-related issues, and we are involved with joint sessions with the Division of Nuclear Physics, and Fora on International Physics, History, and Education . The climate change and nuclear proliferation sessions at the March meeting, organized by Barbara Levi and Ben Tannenbaum were very well attended, and we are hoping the sessions in April are similarly popular. As I begin my term as Chair my goal will be to continue to increase the visibility of the Forum, both through the sessions at our national meetings, as well as other events, and also to promote active APS members to fellowship in the APS through our Forum. I look forward to working with Exec. Committee members, as well as Forum members in these tasks, and am eager to hear from any of you with suggestions as well as offers of volunteering to help in any of these tasks.

Lawrence M. Krauss
krauss@genesis1.phys.cwru.edu

Student Fellowships in Physics and Society

The American Physical Society Forum on Physics and Society (FPS), in partnership with the Society of Physics Students and the APS Forum on Graduate Student Affairs, proudly launched the *Student Fellowships in Physics and Society* this year.

The primary goal of the Student Fellowship in Physics and Society is to provide research and project opportunities for undergraduate and graduate students interested in physics and society, and to raise the awareness of applying physics to problems in society as a career and as an important undertaking by members of the physics community.

There are three objectives of the program.

- First, some students who are exposed to issues where physics impacts societal issues will choose to make careers in this area. These students will provide a badly needed younger generation of technically literate policy researchers, analysts, and leaders.
- Second, there are many more technical issues on the interface between physics and society than there are physicists working on them. Putting talented young people to work on these problems will help society and the physics community.
- Finally, students involved in projects applying physics to social issues will communicate their excitement to fellow students and faculty members in their institutions and nationally, thus raising the awareness of the entire physics community.

The Fellowships are open to undergraduate or graduate students in physics who will be awarded up to $4,000 each to support a project that applies physics to a societal issue.

The 2006 fellows are:

Lee Massey, an undergraduate physics student at the University of Wisconsin, River Falls; and a mechanical engineering undergrad at the University of Minnesota. Mr. Massey will be preparing a report on "the current state of research in the filed of alternative renewable fuel sources for use in vehicles and their realistic possibilities, shortcomings, and the challenges that are being faced during research and development.

Eric Flumerfelt and Matthew Salvitti, both physics undergraduates at Juniata College. Their project will address the fundamental misconceptions amongst high school students and undergraduates about radiation, such as failing to understand the distinction between irradiation and contamination. Specifically, they will develop an educational module on radiation that will accompany a larger project underway at Pacific Northwest National Laboratories studying the detection capabilities of radiation portal monitors.

For more information, go to: http://www.aps.org/units/fps/index.cfm or http://www.spsnational.org/programs/fellowship.htm

Philip W. Hammer
bhammer@fi.edu

ARTICLES

How Much Warhead Reliability Is Enough for a Comprehensive Nuclear Test Ban Treaty?

David Hafemeister

I. Introduction

The National Nuclear Security Administration (NNSA) selected the winning design from the two nuclear weapons laboratories for the reliable replacement warhead (RRW) on March 2, 2007. The winning design by the Lawrence–Livermore National Laboratory was the more cautious design, and had been tested previously. The Los Alamos design was more creative, but had not been nuclear tested. With the Cold War over, NNSA is planning to make warheads that are less constrained in weight and, in principle, more reliable. The Congress and the Executive Branch have agreed that RRW will not be tested before it enters the stockpile. Of course, this does not guarantee that the decision not to test could not be reversed in the future. The JASON group will comment on the RRW designs during the next year and the American Association for the Advancement of Science will release its report on the RRW in March 2007. Our discussion is intended as background material to help understand the RRW decisions and reports. On March 6, a session at the Denver APS meeting considered the RRW and nuclear missions. Talks were given by John Harvey (Director of NNSA Policy and Planning), Lt. General C. Robert Kehler (Deputy Commander of STRATCOM), Bruce Tarter (Chair of the AAAS–RRW Study), Sidney Drell (Stanford), Ivan Oelrich (Federation of American Scientists). The need for the RRW has been called into doubt by the 2006 JASON report that concluded the following: [1]

> "Most primary types have credible minimum lifetimes in excess of 100 years as regards aging of plutonium; those with assessed minimum lifetime of 100 years or less have

clear mitigation paths that are proposed and/or being implemented...There is no evidence for void swelling in naturally aged or artificially aged •–Pu samples over the actual and accelerated times scales examined to date, and good reason to believe it will not occur on times scales of interest, if at all. Systems with large margins will remain so far greater than 100 years with respect to Pu aging. Thus, the issue of Pu aging is secondary to the issue of managing margins."

There is a strong consensus in the US that the *primary* mission of nuclear weapons is to deter nuclear attacks by other nations. However, there is also a strong consensus that nuclear weapons do not deter terrorism by non-state actors. These views were summarized by former Secretaries of State George Shultz and Henry Kissinger, former Secretary of Defense William Perry, former Chair of the Senate Armed Services Committee Sam Nunn and others, who commented in the Wall Street Journal of 4 January 2007 that "reliance on nuclear weapons for this purpose [deterrence] is becoming increasing hazardous and decreasingly effective." [2] They also recommended ratification of the Comprehensive Nuclear Test Ban Treaty (CTBT) by "Initiating a bipartisan process with the Senate, including understandings to increase confidence and provide periodic review, to achieve ratification of the Comprehensive Test Ban Treaty, taking advantage of recent technical advances, and working to secure ratification by other key states."

The main technical issue that blocked CTBT ratification in 1999 was the following: "Will nuclear weapons be sufficiently reliable if they are not tested for centuries?" This question is somewhat misleading since a nation can always withdraw from the CTBT under Article IX when its "supreme interests" are jeopardized. The other main CTBT issues have been or are being solved sufficiently for ratification by the Senate:

(1) CTBT Effective Verification. The CTBT will be "effectively verifiable" when the International Monitoring System is complete and because regional seismic monitoring has greatly improved, along with improvements with seismic arrays and analysis, interferometric synthetic aperture radar and cooperative monitoring. The level at which cheating could take place would not significantly threaten US national security, according to the Nitze–Baker criteria used for the INF and START I-II treaties.[3] The National Academy of Sciences (NAS) 2002 study on the CTBT concluded the following on monitoring with a fully deployed primary seismic network: [4]

> Underground explosions can be detected and can be identified as explosions, using IMS data, down to a yield of 0.1 kt [tamped] in hard rock if conducted anywhere in Europe Asia, North America and North Africa. In some locations of interest, such as Novaya Zemlya, this capability extends down to 0.01 kt or less.

(2) CTBT (with–compliance) vs. no–CTBT vs. CTBT (with–evasion). The NAS panel examined these three situations for seven nations (Russia, China, India, Pakistan, North Korea, Iraq and Iran), concluding the following: [5]

> States with extensive prior test experience [Russia and China] are the ones most likely to be able to get away with any substantial degree of clandestine testing, and they are also the ones most able to benefit technically from clandestine testing under the severe constrains that the monitoring system will impose….Countries with lesser prior test experience and/or design sophistication would also lack the sophisticated test–related expertise to extract much value from such very–low–yield tests as they might be able to conceal….The worse–case scenario under a no–CTBT regime poses far bigger threats to US security interests—sophisticated nuclear weapons in the hands of many more adversaries—than the worst–case scenario of clandestine testing in a CTBT regime, within the constraints posed by the monitoring system.

(3) Nuclear Safety. Only one US nuclear weapon accident has taken place since 1968, which was the 1980 accident of a liquid–fueled missile. This accident did not spread radioactivity and is now irrelevant since all liquid–fueled nuclear missiles have been decommissioned. Only two of the 32 accidents spread considerable radioactivity, which were both aircraft accidents. Practically all (29 of 32) nuclear weapon accidents were with aircraft, which no longer carry nuclear weapons unless placed on alert. The least safe nuclear weapons (nuclear artillery and SRAMs) have been decommissioned and safety procedures have been modified for submarine weapons. A 1992 law required that the Defense Department to do a cost–benefit analysis on safety issues to determine whether new warheads that needed nuclear testing were cost effective. Both Republican and Democratic administrations have since testified that new weapons are not needed to enhance safety. There are no significant safety problems that require nuclear testing to resolve them.

II. NAS Panel Conclusions on Reliability

The NAS panel determined that, under these conditions, US warheads could remain safe and reliable without testing:

- Maintain a high-quality workforce.
- Stockpile stewardship and enhanced surveillance must examine components of weapons. Based on past experience, the majority of aging problems will be found in the non-nuclear components, which can be fully tested under a CTBT.

- The most likely potential source of nuclear-related degradation is the possibility that the primary yield falls below a minimum level needed to drive a secondary. NNSA has concluded that plutonium pits have a minimum lifetime of 45-60 years [now 100 years] with "no life-limiting factors as yet recognized."
- In the past there were few underground nuclear explosions that explicitly served to check the reliability of weapons in the stockpile. Most nuclear tests were used to study and certify new designs and to examine weapons effects.
- Remanufacture to original specifications is the preferred approach for age-related defects, with a highly disciplined process to install few changes without changing the basic nuclear design.

The NAS panel continually asked weapon designers during classified briefings on the enduring stockpile whether testing was needed to resolve the issue under discussion. NNSA weapon scientists always responded that testing was not needed to solve the issue under discussion. The NAS panel concluded the following, based on their experience and the briefings:

> Although a properly focused stockpile stewardship program is capable, in our judgment, of maintaining the required confidence in the enduring stockpile under a CTBT, we do not believe that it will lead to a capability to certify new nuclear subsystem design for entry in the stockpile without nuclear testing -- unless by accepting a substantial reduction in the confidence in weapon performance associated with the certification up until now, or a return to earlier, simpler, single stage design concepts such as gun-type weapons.
>
> It seems to us that the argument to the contrary – that is, the argument that improvements in the capabilities that underpin confidence in the absence of nuclear testing will inevitably lose the race with the growing needs from an aging stockpile – underestimates the current capability for stockpile stewardship, underestimates the effects of current and likely future rates of progress in improving these capabilities, and overestimates the role that nuclear testing ever played (or would be ever likely to play) in ensuring stockpile reliability.

These conclusions are consistent with the fact that the United States has not needed to test in the 15 years since the testing moratorium began in 1992. Each year the US government has stated that it is "confident that the stockpile is safe and reliable, and there is no requirement at this time for nuclear tests."[6] The annual certification on stockpile readiness requires the Secretary of Defense (after advice from Strategic Command and the military services) and the Secretary of Energy (after advice from the three weapon laboratory directors and the NNSA Administrator) to determine whether all safety and reliability requirements are being met without the need for nuclear testing. These reports have always certified that the stockpile does not need testing for reasons of safety or reliability. The NAS panel concluded, with these caveats, that testing is not needed in future years: (1) A robust stockpile stewardship program, (2) no new weapon designs, and (3) the right of the United States to withdraw from the CTBT if the United States decides it must test to defend its national security.

About $7 billion is spent annually to maintain the enduring stockpile (Table 1) and infrastructure under the Stockpile Stewardship Program (SSP) and the Lifetime Extension Program (LEP). Sidney Drell and Robert Peurifoy discussed the technical issues involved with a nuclear test ban.[7] The main threat to warhead reliability is caused by non-nuclear components, which is usually observable without testing on these issues: insufficient tritium, faulty tritium bottles, corrosion of fissile material, degradation of high explosive, low–temperature performance, vulnerability to fratricide neutrons, radar, batteries, fuse switch, neutron generator, faulty cables, trajectory sensors, control systems, rocket motor, gas transfer valve, firing set, and pilot parachute. The warheads in the enduring stockpile have been tested 150–200 times.

Table 1. US Nuclear Warheads in the Enduring Stockpile (2006). Warhead types that are to be partially dismantled are marked with an *. This table does not include the B62 (580 warheads) and W84 (383 warheads), which are scheduled for full dismantlement. [R.S. Norris and H.M. Kristensen[8]]

Type	*Yield*	*Platform*	*Active*	*Inactive*	*Total*
B61/3*	10–350 kt	airplane	200	186	386
B61/4*	10–350 kt	airplane	200	204	404
B61/7	10–350 kt	airplane	215	224	439
B61/11	10–350 kt	airplane	20	21	41
B83	1.2 Mt	airplane	320	306	626
W76*	100 kt	SLBM	1712	1318	3030
W78*	335 kt	ICBM	785	20	805
W80/1*	150 kt	ALCM	1450	361	1811
W87	300 kt	ICBM	0	553	553
W88	475 kt	SLBM	404	0	404
TOTAL			**5306**	**3193**	**8499**

Eleven warheads of each type are annually taken to the Pantex facility, disassembled and examined for deterioration. The JASON group recommended a variety of measures to increase performance margins of warheads, beyond increasing tritium content in the warhead.[9] Warheads will have to be rebuilt; the question is how often with 100–year pit lifetimes. The basic science of warheads and their viability are examined with the technologies listed below:

- visual observation for corrosion, deterioration, cracks and other issues
- chemical, electrical, ultrasonic, diamond-anvil, and other tests
- functional testing of components
- X–ray scattering to search for changes
- deep penetration digital radiography to detect flaws and cracks (core punch)
- laser scattering to study surface imperfections
- synchrotron–based spectroscopy and diffraction
- reassembled device without SNM tested to destruction (Joint Test Assembly)
- subcritical and hydrodynamic tests (Rebound, Holog, Joint Actinide Shock Physics Experimental Research, Atlas pulse power machine, critical assemblies at Device Assembly Facility).
- Dual Axis Radiographic Hydro Test (DAHRT)
- Advanced Simulation and Computing (ASC) program
- accelerated aging of pits with shorter–lived plutonium–238
- National Ignition Facility (not yet functioning)

III. NNSA Definition of Reliability

The United States has not tested each warhead type enough times to determine reliability with high confidence statistics, and certainly not for the effects of aging. Assume ten reliability tests were performed and all were successful. The reliability is not 100 percent with 100 percent confidence, but rather there is a 30 percent chance that reliability is less than 90 percent and a 10 percent chance that reliability is less than 80 percent.[10] Thus, the United States has never known warhead reliability with precision when the warhead entered the stockpile, nor has the United States searched sufficiently for aging effects with confidence tests.

NNSA Definition of Reliability. "The reliability of obtaining the predicted yield of a nuclear weapon has never been assessed because there have never been enough performance [nuclear] tests to establish a statistical reliability. Thus, when a defect type impacting the nuclear explosive package is discovered, the yield performance is evaluated, but no reliability degradation estimate can be made. Therefore, no data is available regarding analysis relating to reliability degradation to predicted yields.….In general terms, reliability is defined as the ability of an item to perform a required function. Implicit in the above definition of 'required function' for one–shot devices, such as nuclear weapons, are the required conditions and duration of storage, transportation, and function."[11] In other words, when a few successful tests give the design yield, the reliability of a warhead type is defined as 1.0, but *without* a confidence level. When actionable defects are detected, NNSA analysis reduces reliability of 1.0 by an amount •R to give a reduced-reliability for each warhead type. NNSA set numerical bounds on reliability reductions •R for 164 actionable defects in 46 warhead types, mostly in the 39 retired warhead types:[12] •R = 0–1% (112 defect types), •R = 1–5% (37), •R = 5–10% (6), •R > 10% (9).

The effect on secondary yield of radiant energy transfer from the primary stage is very nonlinear. A drop in primary yield by a factor of two, for example, could greatly reduce the secondary yield because critical pressures and temperatures may not be obtained. However weapon yield is not a "step function" that varies between two values, zero and certified yield. NNSA is concerned about catastrophic failure of an entire type. This is partially driven by the fact that yield on target is usually much larger than what is needed for particular missions, so the only issue is "does it work." NNSA does not consider the criteria for nuclear missions in any depth since targeting is left to the Strategic Command. Since there are 7 warhead types in the enduring stockpile, a catastrophic failure of one type would shift responsibility to the other six types, with time to repair the catastrophic failure.

IV. Requirements for Reliability and Yield.

NNSA does not consider nuclear targeting for its annual certification report. Since the accuracy of missiles is a statistical phenomenon, statistical analysis is necessary to quantify destruction of targets to determine if warhead degradation is relevant or not. The ability to destroy a target depends on (1) the hardness H of the target (minimum destruction pressure), (2) the yield Y of the weapon, (3) the accuracy of the weapon (CEP, circular error probable), (4) the reliability R of the weapon system (0 to 1), and (5) the number n of warheads attacking a target (taking into account fratricide).[13] The single–shot–kill–probability SSKP is the kill probability of a single warhead on a known target with perfect reliability

of R = 1. We initially assume lethal warheads with SSKP = 1, giving a kill probability for one warhead of P1 = R. If n independent warheads from n missiles are used on a target without fratricide, the kill probability is $Pn = 1 - (1 - R)^n$. Reliability of R = 0.5 gives P2 = 0.75 and P3 = 0.88, and R = 0.25 gives P2 = 0.44 and P3 = 0.58. Except for the case of a pre-emptive attack against a large force, additional warheads on a target can be used for case of reduced reliability.

The kill capability of one W88 warhead of 475 kilotons with 100–meter CEP accuracy attacking a 2000–psi hard target silo with 0.9 reliability is P1 = 0.898. If the W88 yield is reduced by 50%, P2 = 0.99 and P3 = 0.998, and if yield is reduced by 90%, P2 = 0.88 and P3 = 0.96. These results show that large yield reductions do not significantly change P2 and P3.

Table 2. Actionable defects for warheads in the *enduring* stockpile. Those that *required a retrofit or major design change* are marked with an *. This table does not include the 39 retired warhead types. Nuclear components are primary (p) and secondary (s) with number of generic events in parentheses. *Causes* are aging (A), design (D), and production (P), without needing the causes of field induced (F), unknown (U), and combination of design/production (C). *Effects* from the causes are safety (S) (nuclear detonation safety, nuclear material scatter, or personnel safety), operational yield reduction (O), and not applicable (na), and reliability reduction (R, which was not applicable here). [Table 6, FOIA–NNSA]

	primary (p) secondary(s) (number)	*cause A,C,D,P,U*	*effect R,S,O,na*	*FPU: yr after*
B61	p(2)	D*, P	O*, O	1980–86: 3*, 3
	s(2)	P, P	S, S	6, 7
B83	p(0)			1983
	s(0)			
W76	p(2)	P, P	na, O	1979:1, 4
	s(1)	P	O	6
W78	p(3)	P, A, D	O, na, S	1980: 3, 6, 11
	s(0)			
W80	p(2)	D*, P	O*, O	1981-4: 1*, 1
	s(2)	P, P	na, na	1, 5
W87	p(0)			1986:
	s(0)			
W88	p(3)	D*, D*, D*	na*, S*, O*	1988:1*, 2*, 3*
	s(2)	D*, D	O*, O	1*, 3

Testing data obtained from DOE with a Freedom of Information Act (FOIA) request is discussed below.[14] Some warhead types had problems during the early transition to miniaturized warheads with reduced mass and volume.[15] The 1958–61 testing moratorium prevented tests at the time these new warheads entered the force. *Actionable defects*, identified by stockpile stewardship and not by nuclear tests, are listed in Table 2; those marked with an * needed a retrofit or a major redesign. The last column gives the year of discovery of the defect after the first production unit (FPU). Three warheads were retrofitted: (1) B61, 3 years after FPU, (2) W80, 1 year after FPU, and W88 at 1, 1, 2, and 3 years after FPU. This and other data suggest that primary/secondary stages do not show significant aging problems once they have been in the field for a few years. The average age of discovery for the 6 retrofits in Table 2 was 1.8 years after FPU. Five retrofit types were for primaries and one was for a secondary. All six retrofits were from design flaws, causing yield reduction (in 4 cases), reduced safety (1 case) and non-applicable (1 case). The average discovery time for the retired warhead types was 1.9 years after FPU for the 33 primary and 1 secondary stages. Retrofits were caused by design flaws (33), aging (5) and production (1), which effected safety (19), reliability (6), yield reduction (5) and not applicable (4).

Table 2 suggests that primaries are much more vulnerable than secondaries. The two sets of data (retired and enduring warheads) show that the average age of discovery is less than two years after the first production unit. The full data set gives the main cause of diminished reliability, which results from failures of non-nuclear components, not failures of nuclear stages. Drell and Peurifoy quantified warhead reliability as follows: "Since the start of the current stockpile evaluation and reliability assessment program in 1958, about 13,000 weapon evaluations have been conducted. During this period, the failure rate of the nondevice hardware suggests an expected weapon failure rate of 1–2% for the stockpile."[16] Missile failure rates are larger, as pointed out by Richard Feynman, whose estimates were 2% for mature solid–fueled missiles and 4% for all solid–fueled missiles.[17]

These actionable defects for the enduring stockpile were all discovered by stockpile stewardship, except for the W80 cruise missile warhead, which revealed a cold temperature detonation problem. DOE was asked about the "four Product Change Proposals that required underground tests since 1970." The FOIA response below stated that only 4 tests were used; 2 for enduring stockpile weapons and 2 for now retired warheads:[18]

(1) B61/Mod-1 conversion to B61/Mod-7 (Underground testing was used to compare nuclear performance of the insensitive, IHE–primary relative to the former HE–primary being replaced) – 13 years post B61/Mod-1 FPU.

(2) W68 (Underground testing verified a corrective change replacing the primary HE) – 7 years post FPU;

(3) W79 (Underground testing confirmed a safety problem) – 7 years post FPU; and

(4) W80 (Underground testing revealed a cold temperature detonation problem) – within 1 year FPU.

The FOIA response described Major Product Change Proposals for warheads in the enduring stockpile. Six of the 36 proposals affected the primary or secondary and 30 were for non-nuclear components. A new pit was incorporated for the B61 in the first year after FPU and high explosive specifications were changed 3 years after FPU. Thirteen years after FPU the B61/Mod–1 pit was modified for insensitive high explosive for Mod–7, the earth penetrator, which was nuclear tested. The W88 primary and secondary was modified during 1–3 years after FPU. The W80 primary was modified one year after FPU for cold–temperature performance.

Conclusion

The data presented in this paper suggest that US nuclear warheads continue to be reliable, consistent with the annual certification by the Secretaries of Defense and Energy. Plutonium aging is no longer a significant issue, as shown by natural– and accelerated–aged plutonium samples. It is imperative that the missions for nuclear weapons be considered when modernizing and sizing the US nuclear weapons stockpile. NNSA is given very high requirements for yield and reliability by the Department of Defense. But these very high requirements are only relevant for a pre-emptive attack on Russia (perhaps China in the future). The Defense Department maintains these extremely high standards for this type of attack, but this policy leads the United States to reject the Comprehensive Nuclear Test Ban Treaty, an act which is counter–productive to the US goal of reducing the threat of nuclear proliferation. Secrecy and vagueness have prevented a relevant discussion on weapon reliability and its impact on the CTBT. The 6 December 2006 vote on the resolution favoring the CTBT in the UN General Assembly shows that practically all nations strongly prefer a completed CTBT, as they fail to understand US views on the reliability of nuclear weapons. The vote was 172 in favor to 2 against (Democratic People's Republic of Korea and the United States), with 4 abstentions (Colombia, India, Mauritius, Syria). The data presented in this paper suggest that the 172 votes in favor of the CTBT are well justified by the facts.

David Hafemeister
Center for International Security and Cooperation
Stanford University
dhafemei@calpoly.edu

[1] *JASON, Pit Lifetime (McLean, VA: MITRE Corporation, November 20, 2006): 1, 16.*

[2] *G. Shultz, W. Perry, H. Kissinger, and S. Nunn, "A World Free of Nuclear Weapons," Wall Street Journal (Jan. 4, 2007): A15*

[3] *D. Hafemeister, "Progress in CTBT Monitoring since its 1999 Senate Defeat," and "Effective Verifiability of the CTBT," to be published.*

[4] *National Academy of Sciences, Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty (Washington: National Academy Press, 2002).*

[5] *NAS–CTBT study: 70–78.*

[6] *L.F. Brooks, NNSA Administrator (Washington: Arms Control Association, January 25, 2006).*

[7] *S.D. Drell and R. Peurifoy, "Technical Issues of a Nuclear Test Ban," Annual Review of Nuclear Particle Science 44 (1994): 285–327.*

[8] *R.S Norris and H.M. Kristensen, "US Nuclear Forces 2007," Bulletin of Atomic Scientists 63 (January/February 2007): 79–82.*

[9] *JASON, Primary Performance Margins (McLean, VA: Mitre Corporation, 1999).*

[10] *S. Fetter, Toward a Comprehensive Test Ban (Cambridge, MA: Ballinger, 1988): 89–105.*

[11] *FOIA–DOE, E.A. Barfield, DOE Freedom of Information Act Office of Public Affairs, Number 95–207–C, to Hisham Zerriffi (Takoma Park, MD: Institute for Energy and Environmental Research, January 5, 1996). H. Zerriffi and A. Makhijani, "The Nuclear Safety Smokescreen," Physics and Society 29 (April 2000): 3–6.*

[12] *FOIA–DOE: 4–5.*

[13] *D.W. Hafemeister, Physics of Societal Issues (New York: Springer, 2007): chapter 2.*

[14] *FOIA-DOE: 3–6.*

[15] *R.E. Kidder, Assessment of the Safety of US Nuclear Weapons and Related Nuclear Test Requirements: A Post–Bush Initiative Update (LLNL, December 1991). Also see, S. Fetter: pp. 34–42.*

[16] *Drell and Peurifoy: 320.*

[17] *R. Feynman and R. Leighton, Classic Feynman (New York: W.W. Norton, 2005): p. 466.*

[18] *FOIA–DOE: 4.*

COMMENTARY

If Only Rainwater Was Beer

Lowell Grisham

My college roommate Bubba used to say, " I wish rainwater was beer, but it ain't. " Happily, it is a free country, and we have every personal right to believe anything we wish. We can believe that rainwater is beer - or that God created the earth from nothing in 144 hours - but there is a dear price to pay for believing in things that aren't true.

In America you can form a Rainwater Beer Drinkers Society, freely assemble and enjoy fellowship together while sharing communion enjoying your favorite rainwater. You can create and publish books that compare the various beer qualities of different types of rain. You can encourage your followers to learn more about beer-rain, and even fund chemical researchers to publish non-peer-evaluated academic papers listing the chemical properties that prove rainwater is beer. You can fund long lists of experts who testify to the glories of rain-beer.

You can spread those " scientific" findings through any open communication means you wish and quash any critique on your own website. You can call real science " junk" and redefine what science means to allow your own scholars to redefine rainwater as beer.

You can start your own schools and teach your children your truth about rainwater. As long as you can keep your children isolated from the rest of the world you can control their minds. You can build a museum to display the glorious beer qualities of rain. You might even get the Discovery Channel to run something glitzy about your findings. You can grow an industry to promote your theories, create hundreds of " proofs" about rainwater and so flood the argument that the average person will be so overwhelmed that they can't tell rainwater from beer. And whenever you are challenged, you can say you are being persecuted. Say that those people who believe in non-beer-rainwater are all atheists, and they are attacking everyone's religious convictions.

Whenever those pesky scientists try to assert that rainwater is just rainwater, you can demand equal time. After all, saying that rainwater is only rainwater is just a theory. You've got a theory too. The media believes they must report both sides of every issue, so if you can make it an issue they'll give you good quotes. Create a big controversy - " New Findings Suggest the Presence of Hops and Barley in Rainwater. " If any pointy-nosed university academicians challenge you, sic Bill O'Reilly on them. He'll shout ' em down.

In a free country, you've got every God-given right to believe and to express your belief that rainwater is beer. I'll defend your rights, and so will the American Civil Liberties Union. But I don't have to agree with you. We have such a tolerant society that you won't run into too much complaint until you begin to cross lines and try to force others to swallow your beer unwillingly. If your motivated, well-organized minority takes advantage of low-turnout public races like school board elections and gains a majority of rainwater beer candidates on the school board, and if they then require public school teachers to teach the rainwater-is-beer theory alongside the rainwater-is-rainwater theory, you'll wake some people up.

By all means avoid going to court. If you ever go to court you face a substantial obstacle. Courts base their judgments on evidence. You're gonna lose, just like 100 percent of the creationist-intelligent design cases that have made it to trial. Even conservative beer-rain drinking judges will apply the law to the evidence.

The problem with any organization, especially a religious one, attaching itself to a scientific untruth is that the organization loses credibility. It risks losing its children as they grow up and taste rainwater and discover for themselves it is not beer. Unless they are kept in controlled religious isolation, all Christian children will discover one day that evolution is true. If their parents and churches have taught them otherwise, the children are either going to move courageously toward a more progressive faith or fearfully conform to untruth to get along with their authorities or throw religion out entirely. Ferdinand Magellan famously mused, " The Church says the Earth is flat, but I know that it is round. For I have seen the shadow on the moon and I have more faith in the Shadow than in the Church. "

For churches and religious people to be afraid of science and its noble search for truth is a betrayal of our witness that God is truth. Truth is continually unfolding. All new discovery of truth reflects God and adds to our understanding of God. Enjoy the wondrous journey. And have a mug of rainwater on Bubba.

Lowell Grisham
lgrisham@arkansasusa.com
Lowell Grisham is an Episcopal priest from Fayetteville.This article originally appeared in the Northwest Arkansas Times *of Fayetteville, Arkansas and is reprinted with their permission. It was submitted by Art Hobson.*

Reflections on Being a Second Wife

Carol Oen

My husband remembers that he felt some attraction while in high school, but certainly nothing serious. In college, the contact intensified and a deep affection developed. He left college for a year in the Navy, but kept in touch. Returning, he threw himself into the relationship with enthusiasm, spending a great deal of time developing it even further. He was committed.

There came a cooling off period, however. They parted for almost three years while he tried farming. Being apart was too painful, so he returned. He spent the next year earning a master's degree. That year of the master's degree process cemented whatever hadn't been cemented in the affair before. It was during this year that I met him. He thought he could handle two loves.

He and I married, but I found out soon enough that he was still committed to that prior relationship. He couldn't give it up. His devotion seemed to be greater to the other one than to me. I tried to be understanding and patient, waiting to attain my rightful place. After all, he had *married* me.

She, the other woman, was and is Physics. The man is absolutely devoted to her. He swore allegiance to me, but in this bigamous marriage, who really comes first?

A clear answer to that question came while we were at the University of Missouri where Dean was pursuing his doctorate in physics. I went to school, too. For five years we both worked hard. The children came; Kristin when I was a junior, John when I was a senior, and Bill when I was in graduate school. We lived in flimsy converted barracks that stretched in long ragged lines in the veterans' housing area.

Late one afternoon a car drove up and down the streets with a loudspeaker blaring. All residents of the area must move immediately to the basement of the new university hospital, which was about a mile away. A tornado warning! One was coming in our direction. We were instructed to take needed supplies for up to 48 hours.

Bill was an infant. He needed a lot of things, especially diapers. The other children were 2 and 3-1/2 years old. They needed a change of clothes and favorite toys. We would need to take some food, not knowing what would be available at the hospital for the large crowd of people that would be converging there.

I called Dean, who was in the physics building, Stewart Hall, in the middle of the large campus. He had driven, so our car was near him. He had heard nothing about any tornado. He said he couldn't possibly come home right then because he was in the midst of a terrific physics discussion with his advisor. Don, one of my fellow graduate students and a neighbor, took his family to the shelter and then came back for our three children, all our "stuff" and me.

It couldn't be clearer that physics came first. I've read that J. Robert Oppenheimer used the phrase "physics and the life it brings" in a letter to his brother. Jeremy Bernstein uses that to fashion the title of his book, *The Life it Brings: One Physicist's Beginnings*. Perhaps someone ought to write a book about what life brings to the spouses of physicists.

Not all physicists are alike in all respects, but I've had some fun discussions on the topic of physicists with others who have married them. I started telling my tornado tale to one physicist's wife the other day. She stopped me part way through, "You don't have to tell me the ending. I know what will happen!" She noted that homes of physicists need to be fairly quiet because the physicist spends a lot of time thinking. Wives need to self-sufficient and very patient. I agreed with her totally.

It is true that physics brings a good life for the family. There are sometimes opportunities to travel to foreign countries for study or conferences. During some meetings of physicists, spouse programs for accompanying wives sometimes take up the topic of living with physicists. We compare observations and nod sagely. No male spouse has ever been part of such groups. I wonder if they have the same experiences in living with female physicists.

Judy Blume, the well-known author was part of our group at a meeting in Europe. She was then married to a physicist. Her book *Tiger Eyes* is set in Los Alamos, New Mexico. That marriage didn't last long, as I recall. Actually divorce is relatively rare among physicists of my acquaintance, and we've been married over 53 years.

In talking with a hotel staffer during a convention of physicists, I learned that this particular group is not well favored. They sit or stand around and talk, shunning the bars and thus providing less revenue for the hotel.

The bottom line is that we wives all love our physicists dearly. They all dearly love physics and us—in that order.

Carol Oen
Osoen@aol.com

Age Associated Blindness – Self Induced

Grave Concern About Earth Observing Satellites at Science Committee Hearing

"Flying blind" is but one of the terms that House Science and Technology Committee Chairman Bart Gordon (D-TN) used at a hearing earlier this month to describe the nation's rapidly deteriorating system of Earth observing satellites. Gordon's assessment was shared by committee members on both sides of the aisle during this review of a National Research Council report entitled, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond."

"As documented in this report, the United States' extraordinary foundation of global observations is at great risk. Between 2006 and the end of the decade, the number of operating missions will decrease dramatically and the number of operating sensors and instruments on NASA spacecraft, most of which are well past their nominal lifetimes, will decrease by some 40 percent," declared this report. First conceived in 2004, the report was conducted at the request of the NASA Office of Earth Science, NOAA National Environmental Satellite Data and Information Service, and the USGS Geography Division. The first decadal survey undertaken by the Earth Science community, the 400-page report was produced by the80-member "Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future," working under the Space Studies Board. The report can be accessed at http://books.nap.edu/catalog/11820.html

"I don't think the National Academies could be any clearer," said Gordon, sentiments shared by Ranking Member Ralph Hall (R-TX) who added, "this is a problem that needs to be addressed."

One of the major problems highlighted at the hearing was funding. Anthes testified that "while societal applications have grown ever-more dependent upon our Earth observing fleet, the NASA Earth science budget has declined some 30% in constant-year dollars since2000. This disparity between growing societal needs and diminished resources must be corrected." The report's "overarching recommendation," Anthes said: "The U.S. government, working in concert with the private sector, academe, the public, and its international partners, should renew its investment in Earth observing systems and restore its leadership in Earth science and applications."

Moore told the committee that "at a time of unprecedented need, the nation's Earth observation satellite programs, once the envy of the world, are in disarray." After describing the difficult choices that the NRC committee made in narrowing more than 100 suggested future mission concepts into a far more limited set of recommended missions for the next decade, Moore explained that "the recommended NASA program can be accomplished by restoring the Earth science budget in real terms to the levels of the 1990s." Moore described NASA's out-year Earth science budgets as fundamentally flawed and "totally inadequate to accomplish the decadal survey's recommendations." The NOAA budget outlook is mixed, Moore said, and assessing it over the long term is difficult because it "is far from transparent."

Another major problem was outlined by Governor Geringer: "Yes, funding is important but the essential missing element is leadership." "Earth observation is not a priority mission for any designated agency at the cabinet level. Not within NASA, the Department of Commerce, the Department of Interior nor any other Federal agency." Geringer supports the report's recommendations that the Office of Science and Technology Policy "develop and implement a plan for achieving and sustaining global Earth observations. Then a single point of contact or program office at the Cabinet level should be established to assure complementary rather than duplicative or fragmented effort for all operational aspects of Earth observation and analysis."

Committee members were obviously troubled by what they had heard ,and realized the consequences of a greatly diminished U.S. Earth observation scientific and technical capability on making sound policy judgements and competitiveness. Chairman Gordon's remark seemed to summarize well his committee's position: "It's not going to be easy to find the necessary money in the current fiscal environment, but given the consequences of inaction, we must try."

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Richard M. Jones
Media and Government Relations Division
The American Institute of Physics
fyi@aip.org http://www.aip.org/gov
(301) 209-3095

REVIEWS

The Long Emergency: Surviving the End of Oil, Climate Change, and Other Converging Catastrophes of the Twenty-first Century

By James Howard Kunstler, (Grove, New York, 2005, 2006). 324 pp. $14. ISBN 0-8021-4249-4 (paper).

The thesis of Kunstler's earlier books is that suburban sprawl and the automobiles needed to navigate it have deprived us of our sense of community. The thesis of the present book is Kunstler's earlier thesis overlaid with the dependence of automobiles on what he refers to as "cheap oil," coupled with the idea that the imminent end of the era of cheap oil will lead us to a "Long Emergency."

"Even after the terrorist attacks of September 11, 2001," he writes, "America is still sleepwalking into the future" (p. 1). "The wonders of steady technological progress under the reign of oil have tricked us ...to believe that anything we wish for hard enough can come true ...wishing ardently that a smooth, seamless transition from fossil fuels to their putative replacements—hydrogen, solar power, whatever—lies just a few years ahead.... A more likely scenario is that new fuels and technologies may never replace fossil fuels at the scale, rate, and manner at which the world currently consumes them" (p. 3).

"It is possible that the fossil fuel efflorescence was a one-shot deal for the human race," he writes (p. 5). "...An unprecedented orgy of nonrenewable condensed solar energy accumulated over eons of prehistory ...created an artificial bubble of plentitude for a period not much longer than a human lifetime.... As oil ceases to be cheap and world reserves arc toward depletion, we will .suddenly be left with an enormous surplus population ...that the ecology of the earth will not support" (p. 7). However, "...humankind will survive ...though not without taking some severe losses in the meantime, in population, in standards of living, in the retention of knowledge and technology, and in decent behavior ...a dramatic die-back, but not a die-off" (p. 5).

Thus, in his first chapter, he lays out the book and beckons the reader to continue for more details. The next two chapters consider the geological and political factors determining oil supplies in recent history and the prognosis for the future. But I was especially interested in the following chapter, "Beyond Oil: Why Alternative Fuels Won't Rescue Us," because I felt that Kunstler's denying a future based on alternative fuels was the key to his forecast of a dismal post-oil future. Here he writes that "all of the non-fossil fuel energy sources ...depend on an underlying fossil fuel economy" and adds that "...without the petroleum 'platform' to work off, we may lack the tools to get beyond the current level of fossil-fuel based technology ...we have an extremely narrow window of opportunity to make that happen" (pp. 100, 102). He seems less dismissive of nuclear fission than of solar and wind energy, but even here he is quick to recognize that nuclear fission (like photovoltaics and wind) is limited to making electricity (which represents only 36% of our energy use). "It means we can have the lights on at night and refrigerate our food, but without the benefit of artificial fertilizers made out of natural gas, and diesel-powered machinery to till the soil at industrial scale, we will have to completely reorganize agriculture" (p. 146).

After a further chapter discussing the further insults to the post-oil world which we can expect from global warming and further medical dangers, he comes to his penultimate chapter "Running on Fumes: The Hallucinated Economy." Just as the stock market crashed in 1929 when the expected increase in the value of stocks bought on the margin failed to materialize, so also have the "dot.com bubble," the Savings and Loan Association fiasco, and "creative" schemes continued to characterize the "hallucinated economy," which Kunstler attempts to describe in a thermodynamic context with a questionable use of the concept of entropy. Most recently, according to Kunstler, this economy has invested its money unwittingly in real estate under the assumption that its value, too, will only continue to appreciate.

The same considerations apply to energy sources. "Economists would rationalize," he writes, "by declaring that ninety-nine years from now we will have colonies on the moon or Mars or under the Sea of Cortez. Or that technology coupled with human ingenuity will solve the problem some other way, perhaps by genetically reengineering human beings to be one inch tall, or booting all our consciousnesses into computer servers where unlimited numbers of virtual people could dwell in unlimited virtual environments of endless cyberspace" (p. 193). "More likely, we will remain confined to the planet Earth," Kunstler rejoins, where the carbon dioxide resulting from burning half the world's supply of oil "is now ratcheting up global warming and climate change, which might well put the industrial adventure out of business before human ingenuity can come up with a substitute for oil" (p. 194).

This brings us to "Living in the Long Emergency," the final chapter. "...Life in the decades ahead ...will become increasingly and intensely local and smaller in scale ...as the amount of available cheap energy decreases" he writes. "All other activities will be secondary to food production, which

will require much more human labor" (p. 239). With oil the resource in most immediate shortage, Kunstler turns to transportation needed both to produce food and to market it. He sees in the Amish and small-scale organic farmers—and the craftsmen and women who support them—the maintenance of agricultural knowledge that will be needed in the Long Emergency.

Kunstler surveys and rates the different parts of the U.S. in their ability to adapt to the Long Emergency and concludes that the most adaptable parts are small cities and towns in the northeast, surrounded by fertile farmland. The key criteria for buildings are 1) ability to walk (or bicycle) to them, 2) ability to heat them, and 3) ability to keep their roofs repaired. This requires sufficiently dense urban living, but not so dense that energy-consuming elevators are needed—Kunstler settles on two-to-five stories as most ideal. He feels the northeast is most adaptable because it has a greater pride in sense of community, also plentiful fertile soil and rainfall.

Air and auto transportation, both of which depend on oil, could be afforded only by the wealthy, and neither to a sufficient extent to maintain public highways or commercial airlines. More realistic modes of transportation, Kunstler argues, are water and electrified rail (provided that nuclear electric plants can be built soon enough)—he recalls the once widespread network of interurban light rail systems, which, he says, can now be rebuilt on the roadbeds of abandoned highways.

As one of the few present occupations that will continue to be viable, teaching, Kunstler writes, will likely become a more respected profession. But it will become more limited in scope, preparing the rest of the population for more useful "hands-on" employment. "...Most non-manual-labor jobs ...do not require anything more than the ability to write a coherent paragraph or perform a few rudimentary operations of arithmetic—which is asking a lot, by the way..." (p. 217).

What especially concerns Kunstler is the emerging feeling that something can be gotten for nothing, which he attributes to the emerging respectability of gambling from the proliferation of casinos—"from students who expect to be given automatic As just for showing up ...to ordinary citizens living wildly beyond their means on credit cards" (p. 302). Instead, "We will have to adjust our attitudes, values, and ideas to accommodate these new circumstances.... In the Long Emergency, nobody will get anything for nothing.... Personal responsibility will be unavoidable, perhaps excessive" (pp. 303-304).

John L. Roeder
Physics instructor
The Calhoun School, New York City
JLRoeder@aol.com

Big Coal: The Dirty Secret Behind America's Energy Future

By Jeff Goodell, Houghton Mifflin, New York (2006), 324 pp., hardcover, $25.95, ISBN-13: 978-0-618-31940-4

Veteran journalist Jeff Goodell tells three separate but interwoven stories in Big Coal. The first is the story of coal as a resource and of our present-day need for coal for cheap energy. Much of our energy from coal comes in the form of electricity, and about half of the electricity in the U.S. today is from coal. The second is the harm to the people who mine it and to the environment both as a major source of pollution and of the greenhouse gas CO2. And the third is the story of Big Coal, the coal-mining companies, coal-burning utilities, railroads, lobbying groups, and industry supporters, which collectively constitutes a formidable political force to promote the interests of the coal industry, frequently at the expense of the public welfare. The influence of Big Coal has expanded considerably since President George W. Bush took office in 2001. Within weeks, Bush began staffing regulatory agencies with former coal industry executives and lobbyists; as of 2006, more than 150 new plants were either planned or under construction in the U.S.

Cheap and plentiful coal and electricity generation have proven to be a natural fit. Chapter 1 describes our ample U.S. reserves. According to a 1974 study, half of our reserve base is recoverable, an estimated 250 years' worth at the present rate of consumption, although a 1989 study concludes that only a much smaller 5-20% is recoverable at present costs. Goodell describes in chapter 5 the astonishingly rapid diffusion of electricity into the U.S. economy, starting from Edison's first electric power system in lower Manhattan in 1882. In 1905, fewer that 10% of U.S. homes were wired for electricity; by the late 1920s, 75% were, including almost all homes in cities. And the average price of electricity fell from $4.53/kWh in 1892 to $0.62/kWh in 1927 and $0.47/kWh in 1937, still high by today's standards. The new electric power industry was based mostly on large and efficient coal-fired power plants. Today's coal plants, many built in the 1960s and 1970s before pollution controls were enacted, produce electricity so cheaply that it is difficult for other types of power plant to compete, although in recent years, natural gas-fired plants have given them a run for their money.

But there has always been a downside to coal, a downside of exploitation, pollution, and evasion of social responsibility. Chapters 2 and 3 describe how coal mining in West Virginia has made a few people extremely wealthy while wages of coal miners have lagged far behind productivity, and the state as a whole has remained poor and environmentally degraded. Mountain top removal has resulted in more frequent and more

intense floods, and the ground water has been polluted with heavy metals. Mining is one of the most dangerous occupations in the U.S.; mine safety legislation has come about only after disasters have brought working conditions to the public eye.

Chapter 6 considers air pollution. Tens of thousands still die prematurely in the U.S. each year from burning coal. The 1970 Clean Air Act helped considerably; since then, SO2 emissions per unit energy from coal plants have fallen by 77%, NO2 emissions by 60%, and large soot particles by a remarkable 96%. Nevertheless, power plants still account for two-thirds of all SO2 pollution, 22% of all nitrogen oxides, a third of all mercury emissions, and nearly 40% of all CO2. The industry response has frequently been lobbying for favors and loopholes, evasion, and delay. To cite one example: Although under Presidents George H. W. Bush and Bill Clinton the EPA moved to strengthen mercury regulation, in 2003 under pressure from the coal industry the EPA de-listed coal plants from the list of sources of hazardous air pollutants, and put in place a cap-and-trade arrangement preferred by the industry; many passages in the new EPA regulations were written by coal industry representatives and lawyers. As of the writing of the book, the de-listing was still in effect. Other instances of Big Coal meddling in government are detailed in chapters 6 and 7.

Big Coal is a significant player in the global warming issue, both as a producer of CO2 emissions and as a shaper of public opinion and of public policy, as detailed in Chapters 8 and 9. Global warming first caught the public eye at the testimony of climate researcher James Hansen before the U.S. Senate during the hot, dry summer of 1988. Some prominent scientists and climate modelers suggest that the world can tolerate 3.5°F of warming without major disruptions; this means that CO2 levels must be stabilized at between 400 and 500 ppm. At the rate the world is going, we'll pass the point of no return around 2017. Big Coal's response has been twofold: In the early 1990s it participated in the public relations campaign of the Information Council on the Environment to "reposition global warming as theory rather than fact," a campaign that despite its lack of scientific basis has been remarkably successful; and it has pushed forward on plans for more than 150 new power plants in the U.S. Although the new integrated gasification combined cycle (IGCC) technology is more efficient and much more amenable to carbon sequestration, only a handful of the new plants will use IGCC technology; Big Coal cites studies showing they are 10 to 20% more expensive to build, and that IGCC is an unproven technology, claims that are disputed by Goodell. Then there is the problem of China, described in Chapter 10. According to the International Energy Agency (IEA), the equivalent of 1400 1000 MW coal-fired power plants will be built globally by 2030, half of them in China. Yet China is unlikely to cut its CO2 emissions from burning coal, if to do so means risking its economic growth and political stability.

Despite the apparently intractable problem of reducing CO2 emissions in the face of increasing world-wide demand for cheap electricity from coal and the resistance of the coal industry to change, Goodell is hopeful. In the Epilogue he outlines a plan of action:

1. We must recognize the two enormous problems facing the world in the coming years, the end of cheap oil and the arrival of global warming.
2. We must recognize that the barriers to change are not technological but political; near-zero-emission coal plants (IGCC plants with sequestration) can be built today.
3. We must make the externalities of coal and coal-fired plants clearer to the public, and we must make it easier for smaller, more local forms of power generation to get onto the grid.
4. We must begin preparing for the consequences of global warming.

He ends with an exhortation for innovative thinking: " ... it's within our grasp to figure out less destructive ways to create and consume the energy we need. Ultimately the most valuable fuel for the future is not coal or oil, but imagination and ingenuity. We have reinvented our world before. Why can't we do it again?"

This is an important book, carefully researched with a complete set of notes and references. It documents well the environmental and social price we pay for cheap electricity from coal. It's worth reading by anyone interested in energy, the environment, public policy and, in particular, coal and electricity and the way they work together in the U.S.

Louis Schwartzkopf
Professor of Physics
Minnesota State University, Mankato
louis.schwartzkopf@mnsu.edu

Living with the Genie: Essays on Technology and the Quest for Human Mastery

Edited by Alan Lightman, Daniel Sarewitz, Christina Desser (Washington, DC, Island Press, 2003), ISBN 1-55963-419-7. $27 hardcover. 301 pp.

The share price of Apple rose 10% with the introduction of the iPhone. What this device costs or does are hardly important—Apple will make something new, and people will eagerly buy it. Why shouldn't they? In a world that equates technology and progress, the latest gadget places its owner

on the leading edge of technology, pushing society towards a bright and happy future.

American science was institutionalized in the wake of the tremendously successful Manhattan Project, and it reflects a faith that science provides the raw materials for technology and the position of power that the United States enjoys today. It is assumed that one cannot know beforehand which research will provide dividends, but that the benefits of a broad research portfolio will be vast. But there are drawbacks—threats to our lifestyle, society, and civilization— and many believe we should make scientific choices carefully, with the potential drawbacks in mind. "Living with the Genie" is a collection of ideas from writers, scientists and philosophers concerning what kinds of technology we should pursue and how we can ensure that our research is working for us, and not the other way around.

Philosopher Philip Kitcher argues in "Living with the Genie" that our research program largely reflects curiosities of scientists. He complains that evidence supporting the idea that progress is best achieved through serendipitous discovery is anecdotal and held to lower standards of proof than is the science itself. Kitcher describes a better method that would bring a broad cross-section of society to produce a ranking of projects to be carried out. Kitcher's scenario is idealistic, but it lays out a case for more democratic involvement in decisions, and a concrete understanding of how research and benefits are connected.

Shiv Visvanathan proposes an implementation of democratic communication in science based on the model of Truth Commissions, which could inform decisions to deploy new strains of grain, or building dams, etc. Visvanathan emphasizes the need to understand the benefits of current practices before they are displaced by newer technology. In his native India, novel technologies have been implemented without discussion, sometimes doing more harm than good. Truth Commissions offer a form of dialog that avoids presumptions of good and bad, providing an environment in which promoters and skeptics of technology could find compromise. This would be the kind of conversation that Kitcher imagines would produce decisions based on a thoughtful consideration of how science can be best used to our advantage. "Living with the Genie" is part of this more nuanced discussion.

While most authors recognize weaknesses in the way technology now connects to society, they don't suggest that certain avenues of research be closed. Lawyer Lori Andrews describes reproductive technologies as a case in which withdrawal of government support for research has merely prevented regulation.

Kathy Schick and Nicholas Toth give an anthropologist's history of technology. They agree with inventor Ray Kurzweil that we shouldn't sacrifice potential benefits to avoid hypothetical dangers, particularly when it is difficult to foresee behind which doors the hazards lie. They argue that we've proven ourselves adept at keeping one step ahead of disaster, and we should continue to pursue all research with a system like Visvanathan's to avoid problems in implementation.

The most hysterical fears of technology focus on threats to our lives, but the most interesting ones concern technology's ability to make us less human. Richard Powers describes software called "DIALOGOS," which allows him to correspond with any person, dead or alive, real or fictional. When Powers writes to young Werther, of Goethe's novel, the software takes clues from his mail and the web to respond in a believable way. DIALOGOS awakens other characters in the book, who write to Powers about their mutual friend. As Werther is exposed to new information, he tries to understand his relationship to Goethe; realizing that his life has been scripted, he kills himself; the program is writing a story that would surely fascinate Goethe.

Powers is absorbed by his lifelike and increasingly self-aware correspondents, withdrawing from human society and leaving emails from actual people unread. The program is responding to Powers, but it also has access through the web to a deeper collection of human wisdom and experience than Goethe ever had. It is as real as the novel. A machine that can write better books or be a more interesting conversationalist than real people threatens to take away our humanity, but Powers is optimistic that it offers a new way of sharing the human experience. It is as much art as technology.

Alan Lightman's essay concludes the book on a similar note. He complains that his days are now so efficiently filled that every moment is allocated to some productive task, leaving no room to breathe. When technology and progress are equated, and every possible step towards speed and efficiency is seen as a form of good that should be taken up without hesitation, we don't have time for the self-reflection that makes us human. He claims that this life has taken from him something of his inner self.

But Lightman's essay is an act of self-reflection—he has made time to assess what kind of life he wants, and what role technology should play in it. If the sweep of technology takes away his humanity, it is because he allows it to. Powers also takes responsibility, deleting the program from his computer and ending his essay on the sidewalk, talking with a neighbor.

Science and Technology have been a tremendous source of goodness. The authors in "Living with a Genie" point out many problems with the way that science interacts with society today, but this is not an anti-science book. They advocate for a deeper consideration of how we can pursue our inquiry in

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a way which is safe and responsible to our values, but they are optimistic that by accepting responsibility for pausing and taking stock of what we want from technology, we can remain its master.

Matthew Sharp
University of Chicago
sharp@uchicago.edu

AMERICAN PHYSICAL SOCIETY
Forum on Physics and Society
One Physics Ellipse
College Park, Maryland 20740-3844

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Co-Editors: Al Saperstein, Physics Dept., Wayne State University, Detroit, MI 48202, ams@physics.wayne.edu; Jeff Marque, Senior Staff Physicist at Beckman Coulter Corporation, 1050 Page Mill Rd., MSY-14, Palo Alto, CA 94304, jjmarque@sbcglobal.net. **Reviews Editor:** Art Hobson, ahobson@comp.uark.edu. **Electronic Media Editor:** Andrew Post-Zwicker, azwicker@pppl.gov. **Layout at APS:** Leanne Poteet, poteet@aps.org. **Website for APS:** webmaster@aps.org. ***Physics and Society* can be found on the Web at http://www.aps.org/units/fps.**