FPS NEWSLETTER - OCTOBER 2004

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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 ELECTIONS

The 2005 election of officers is now open! The ballot for the next Chair-Elect, Vice-Chair and two members of the Executive Board is now available at http://www.physics.wm.edu/ballot.html
All are urged to vote--it is your way of influencing the future of the Forum. The primary responsibility of the Vice-Chair is to coordinate nominations for Forum APS fellows. He/she then succeeds to Chair-Elect to arrange Forum sessions at APS meetings, and then Chair to coordinate the tasks of the Forum. This year both the Chair-Elect and Vice-Chair positions are available due to the resignation of last year's Vice-Chair. Please vote before November 30, 2004.

CANDIDATE BIOS and STATEMENTS

Candidates for Chair-elect 2005

Caroline L. Herzenberg;
Tony Fainberg

Caroline L. Herzenberg

Background:

Dr. Herzenberg is retired from Argonne National Laboratory, where she worked in a number of different areas of applied physics. After receiving a Ph.D. in experimental nuclear physics from the University of Chicago, she held faculty positions at Illinois Institute of Technology, the University of Illinois at the Medical Center, and California State University Fresno, and also held a research position at IIT Research Institute. She is a Fellow of the APS, the AAAS, and AWIS; and served as national president of the Association for Women in Science. Within the APS, she chaired the Committee on the Status of Women in Physics, and was a member of the executive committees of both the Forum on Physics and Society and the Forum on the History of Physics. Her work in applied physics has included research in experimental nuclear physics, research in Mossbauer spectrometry including applications to analysis of returned lunar samples, instrumentation development and allied areas. She has also worked in the areas of chemical and radiological emergency preparedness and arms control.

Statement:

The Forum on Physics and Society has a potentially more significant role at present than in the past, as important issues are now present both with respect to how contemporary American society is affecting science, and how scientific knowledge and its technological implications are affecting our society.

Science relies on freedom of inquiry and objectivity. To the extent that our society attempts to curtail freedom of inquiry or to distort objectivity, the wellbeing of science – as well as the wellbeing of our society - is at risk. During the last few years, the role of science and scientists in our society has been subject to an unprecedented degree of misuse. The scientific advisory system has been undermined. Scientific analysis from federal agencies has been suppressed and distorted. Funding for scientific research has lagged while large amounts of funding have been spent unproductively in other areas. But sound public policy must be predicated on sound science. It is important for physicists to be able to offer informed advice and provide guidance on significant science-related issues in our society, and we may need to work to assure that the guidance that we provide is understood and not disregarded. Persistence may be required in efforts to encourage decision makers in American society to understand and accept the results of objective analyses, even when the outcomes are not the outcomes that policy-makers might prefer.

Continuity of Forum activities is of importance, and we should extend our work in examining the implications of scientific analyses of societal issues. We need to continue to address the whole range of societal issues in which physics plays a crucial role and in which we have appropriate expertise, including arms control and security issues, energy and environment issues, and international scientific cooperation. We should also continue to promote public understanding of science and emphasize improving the quality of science education. In addition, we need to continue to support and develop the various mechanisms by which physicists can express their concerns and interact with each other in these various areas, and to extend our outreach so as to encourage more physicists to participate in Forum activities and join us in the Forum.

As incoming chair-elect of the Forum on Physics and Society, I will work to maintain an active engagement of physicists in societal issues, and I will work to strengthen the Forum on Physics and Society.

Tony Fainberg

Background:

PhD, Experimental Particle Physics, UC Berkeley 1969. Research in residence at CERN, working for University of Turin, Italy, 1970-72. Res. Prof. At Syracuse University, in residence at Brookhaven National Laboratory,1973-77. Switched to applied physics and systems studies at Brookhaven,working in Technical Support Organization for Nuclear Safeguards, 1977-1983.APS Congressional Science Fellow, 1983-84, in office of Sen. Jeff Bingaman, working in science policy, national security issues and foreign policy.1985-1995, senior analyst at Congressional Office of Technology Assessment, working in national security issues, from missile defense to nuclearnon-proliferation as well as early work on the uses of technology to defend against terrorism. 1996-1999, Office Director, Policy and Planning for Civil Aviation Security, Federal Aviation Administration. 1999-2002,Division Director, Advanced Systems Concepts Office, Defense Threat Reduction Agency. 2002, Science Advisor, Transportation Security Administration. 2002-2004, Office Director and Program Manager, Science and Technology Directorate, Dept. of Homeland Security. Former Chair, Forum onPhysics and Society; former member, Panel on Public Affairs, APS; Fellow, APS; member AAAS.

Statement:

As our society and culture have changed rapidly under new stresses, the public is often late to realize that the playing field and its rules have changed and that goalposts have been moved. Being within an inertial frame, we may not realize for a while that our velocity is appreciable relative to an outside observer. Some of the stresses are political and military -- clearly the terrorist attacks on the US have had a major effect on the way we think and the manner in which the body politic behaves. Other stresses are global in scale, less direct, and less acute;

some obvious ones are (likely) anthropogenic global climate change and (certainly) anthropogenic water scarcity.

As we have naturally focused on terrorism since 9/11, the nation has apparently lost some interest in other issues, some of which may be at least as important. One thing physicists can do, as physicists, is to remind the nation that, e.g., nuclear non-proliferation is as vital to the national interest as counterterrorism. In fact, the two are clearly linked: the more nuclear weapons are available, the more likely it is that, somehow, they maybe used in a terrorist mode. Outside observers, in Europe and Asia, have not forgotten the importance of non-proliferation, and, indeed, Europeans have fortunately taken the lead in the case of Iran, while the US has been otherwise engaged. And, in the longer, but not that long, term, climate change could affect many more lives directly than terrorism yet has.

What can physicists, as physicists, do in general to help the nation? While the body politic is less aware, dwelling within its inertial frame, that current events may divert us from other problems that seriously threaten our national interest (and, indeed, often the interest of the planet), physicists sometimes have the expertise and analytical discipline to bring reality back to the forefront of political consciousness. We are most effective and most heeded, like anyone else, in areas about which we know something. So we have to focus our activities on areas of our expertise, so as to avoid spending our chips of influence on topics about which we have no particular claim to pontificate.

Physicists, through the APS, have been effective at influencing public policy in areas such as missile defense and energy conservation, and could be equally effective in analyzing, e.g., climate change, energy policy, and water scarcity issues for the public and for decision makers.

I applaud the past activities of the APS to apply physics knowledge and expert authority to scientific and technical issues that affect society at large, and would, through the Forum on Physics and Society, work to continue and expand such efforts, through studies, educational activities, and public outreach. I would seek input from the membership of the Forum on the proper prioritization of topics of activity and on improving our effectiveness in moving public debates and policy decisions.

Candidates for Vice-Chair 2005
George Lewis
Charles Ferguson

George Lewis

Background:

George Lewis is a Principal Research Scientist at the Massachusetts Institute of Technology and Associate Director of M.I.T.'s Security Studies Program. He has a Ph.D. in experimental solid state physics from Cornell University (1983). During the next several years, while a Research Associate in Cornell's Department of Applied Physics working on ion beam lithography, he participated in number of educational projects on nuclear arms race related issues, and decided to pursue a career working on technical aspects of international security issues. Following a year each at Cornell's Peace Studies Program and Stanford's Center for International

Security and Arms Control, he came to M.I.T. in 1989. His research currently focuses on the technology of ballistic missile defenses, the implications of the proliferation of ballistic missiles and of defenses against them, security aspects of satellites and outer space, and the security of nuclear power plants. He is a Fellow of the APS and was a co-recipient (with Lisbeth Gronlund and David Wright) of the 2001 Joseph A. Burton Forum Award of the APS. He is an Associate Editor of the journal *Science and Global Security*, and since 1990 he has been a co-organizer of the annual *International Summer Symposiums on Science and World Affairs*, which assist young scientists from many countries who are working on, or planning to work on, security problems as a career. In his hometown of Duxbury, Massachusetts (which is within the Emergency Planning Zone of the Pilgrim nuclear power plant in Plymouth, Mass.) he is a member of the town's Nuclear Advisory Committee. He and his wife Hillary have four foster children, all refugees from war-torn Southern Sudan, and four dogs.

Statement

Many national policy issues hinge on scientific or technical considerations. This is nowhere clearer than in the area that I have chosen to work in, the defense and international security field. However, as we all know, important policy decisions are sometimes made on the basis of poor, biased, incorrect, or even non-existent scientific advice. There is a clear need for unbiased scientific and technical analyses and advice on policy issues, and this need is now arguably greater than ever, given the decrease in technical expertise within the government and increasing governmental trends towards secrecy. I am well aware of the impact that the APS can have, since I work in a field that has been significantly influenced by APS studies such as the 1987 Directed Energy Weapons Study and the more recent Boost-Phase Missile Defense Study. In fact, my own work has been the subject, and beneficiary, of an APS Panel on Physics and Public Affairs-sponsored study: the 1998 Report of the POPA Ad-Hoc Panel on the Technical Debate over Patriot Performance in the Gulf War. I believe that the APS has performed (perhaps not often enough) and can continue to perform an important public service by providing the best possible scientific advice on carefully selected policy questions. However, the ability of the APS to do so is limited if its own members do not understand either the importance of these issues or the significance of their own scientific society weighing in on them. Although the Forum has many roles to play, I see this as its fundamental one: to educate the members of the APS about the societal implications of their work and to encourage both individual members and the Society itself to play a larger role in the national and international debate on political and societal issues that depend on science and technology.

Charles Ferguson

Background:

Dr. Ferguson is a Senior Fellow in Science and Technology at the Council on Foreign Relations. His term as Member-at-Large on the Forum's Executive Committee will end in December 2004. He has helped organize APS Meeting sessions on radiological terrorism and nuclear nonproliferation. Since late 1997, he has applied his scientific training to public policy issues, in particular, nonproliferation, nuclear terrorism, and nuclear safety. Currently, he is directing a project examining the nuclear fuel cycle and the nonproliferation regime. Prior to his current position, he was a Scientist-in-Residence at the Monterey Institute's Center for Nonproliferation Studies (CNS). At CNS, he co-directed a project to assess the dangers of nuclear terrorism and is the lead author of the new book *The Four Faces of Nuclear Terrorism*. As part of that project, he has advised the U.S. government on aspects of radioactive materials security. Previous to his work with CNS, he served as a Foreign

Affairs Office in the Office of Nuclear Safety at the Department of State. He has also worked as a Senior Research Analyst and Director of the Nuclear Policy Project at the Federation of American Scientists. He has done physics research at the University of Maryland, the Space Telescope Science Institute, the Harvard-Smithsonian Center for Astrophysics, and the Los Alamos National Laboratory. Dr. Ferguson earned a B.S. with distinction in physics from the U.S. Naval Academy in 1987, an M.A. in physics from Boston University in 1994, and a Ph.D. in physics from Boston University in 1996. After graduation from the Naval Academy, he served as an officer on a U.S. nuclear submarine.

Statement:

Long before the impact of globalization was fully felt in economics, physicists around the globe shared the common languages of science and mathematics that helped them overcome cultural differences. Today, I am concerned about the remaining gap between political leaders and scientists. Most political problems facing the world have a substantial technical dimension, and globalization teaches us that no country can isolate itself. The Forum on Physics and Society has served as a tremendous resource for more than thirty years. Nonetheless, I believe that we should strive to do a better job at bringing scientific analysis to political issues that have technical components, at educating politicians and the public about the important contributions of science to society, and at developing a greater understanding of the political process.

Candidates for Executive Committee: 2005

Stephen Benka
Daniel Dietrich
Mark Goodman
Sherrie Preische

Stephen Benka

Background:

Dr. Benka received his PhD in physics from the University of North Carolina in Chapel Hill. He was a solar physicist at NASA's Goddard Space Flight Center and at the Naval Research Lab in Washington DC. In 1993, he joined the American Institute of Physics as an associate editor at *Physics Today* magazine and has now been the magazine's Editor-in-Chief since 1994. In that capacity, he has continually developed, acquired, and brought to publication many dozens of feature articles at the interfaces of science with society, government, education, and the global community. Recent special-issue topics that he spearheaded include National Security (12/00), The Energy Challenge (04/02), and Reaching Out to Undergraduates (09/03). He is a Fellow of the American Physical Society.

Statement:

With the responsibility for a publication that reaches 120,000 members of ten different physics-related societies, I see a vital part of my job as raising our collective awareness of what physics and physicists offer the larger world in matters of concern to all people. Such matters include education, security, civil liberties and human rights, the environment, international relations, energy, health, military technology, and more. In short, as the mission of AIP declares, "promoting the advancement and diffusion of the knowledge of physics and its application to human welfare." The FPS's members are a wellspring of ideas, words, and actions on behalf of promoting that goal. As a member of the FPS's Executive Committee, I will better optimize my service as a bridge between our Forum and the much wider community of scientists, whom we all wish to further energize.

Daniel Dietrich

Background:

Dr. Dietrich is a senior physicist at the Lawrence Livermore National Laboratory, where he has worked for over twenty five years. He has led a diverse series of projects involving the application of science to the national interest, ranging from accelerator based atomic physics to oceanography. His current activities involve developing radiation detection systems in support of the Department of Homeland Security and the Department of Energy emergency response community. After receiving his PhD (1975) from the State University of New York at Stony Brook he held post doctoral fellowships at the University of Arizona and at the University of California at Berkeley. He joined the staff at LLNL in 1979. During 1985-1986 he held senior fellowship positions at Oxford University and at the University of Paris.

Statement:

The Forum on Physics and Society provides a venue for effective two-way sharing of knowledge between physicists and policy makers as well as the general public. The involvement of physicists in national security has been a continuous activity since before the Manhattan project. With the advent of the Department of Homeland Security comes a new interest in creative technical solutions to problems of national security along with new opportunities associated with issues such as: 1) the appropriate funding balance between basic research and applied development; 2) the need for classification balanced against the efficiency of open competition, and 3) the role of technical input in the formation of policy. I believe that my background brings a valuable perspective to the FPS. I would encourage the FPS to sponsor a study of the efficacy of DHS efforts to thwart rad/nuc threats and how those efforts interface with chem/bio efforts. I would encourage physicists who work in the classified community to present their findings along with their perspective on the societal implications at the FPS sessions at the APS March and April meetings. I would also promote development of an objective, knowledgeable review system available to advise policy makers and their staff.

Mark Goodman

Background:

Dr. Goodman is a Physical Scientist in the Office of Multilateral Nuclear Affairs at the Department of State, working on nuclear nonproliferation at the Department of State, and before that with the Arms Control and Disarmament Agency, since 1995. He oversees U.S. financial and technical assistance the International Atomic

Energy Agency, including for safeguards to verify that states are not diverting nuclear materials or misusing nuclear facilities to produce fissile material for nuclear weapons. He also advises on verification and nuclear fuel cycle issues in dealing with the nuclear proliferation challenges in North Korea and Iran, the opportunities in Libya, and a prospective Fissile Material Cutoff Treaty. After receiving his Ph.D. in theoretical particle physics at Princeton University in 1986, Goodman held postdoctoral research positions at the Institute for Theoretical Physics at University of California-Santa Barbara and Rutgers University. His work at Harvard's Center for Science and International Affairs formed part of a 1991 book with recommendations on U.S. nuclear weapon policy after the Cold War. As an AIP Congressional Science Fellow in 1992-93, Goodman worked for Senator Kent Conrad (D-ND) on science, technology, energy, environment, and defense issues. He contributed to reports by the Office of Technology Assessment on civilian satellite remote sensing, and the reports of the Advisory Committee on Human Radiation Experiments.

Statement:

The mechanisms and institutions for members of the scientific community to address societal issues, where scientific expertise intersects public policy, have eroded significantly in recent years. The Forum on Physics and Society provides one such mechanism for APS members, but it too has become less active. I have had the good fortune to work for two of the finest organizations that brought scientific and technical expertise to bear on public policy issues – the Arms Control and Disarmament Agency (which was merged into the Department of State) and the Office of Technology Assessment (which was eliminated). The unfortunate demise of these institutions has made it harder for decision makers in the Executive and Legislative Branches to obtain balanced technical advice on many important issues. Questions have also been raised about the politicization of the scientific advisory process. My chief priority as Forum Councilor would be to work on ways to restore, strengthen and ensure the integrity the institutional mechanisms for interaction between scientists and government.

Sherrie Preische

Background:

Dr. Preische is the Executive Director of the New Jersey Commission on Science and Technology, the state agency charged with promoting state economic development through science and technology particularly by building strong research ties between the state's universities and industry and new tech-based companies. Prior to taking this position, she served as a science and technology policy advisor to Governor McGreevey of New Jersey. This work included detailed recommendations on how New Jersey's research universities can partner with our high-tech business sector and working closely with university leadership to put these ideas in place. Dr. Preische spent four and a half years working for Congressman Rush Holt (who has himself been active in the Forum) in several capacities, including fundraising for his first successful campaign, in his Washington office supporting the Congressman's focus on science and research issues, and three years running his New Jersey Congressional office. She holds a doctorate in astrophysical sciences from Princeton University and has conducted research in fusion energy at Princeton and in France. She worked for the American Physical Society with Brian Schwartz supporting efforts to expand the public perception of physics and its relevance in daily life. She also served a three year term 1993-96 on the Executive Committee of the APS Division of Plasma Physics.

Statement:

I work daily to promote science, including physics, being done to meet some of society's everyday needs. Having worked for elected officials for several years now, I have a deep respect for the role of our public servants in meeting the needs of taxpayers and that democracy most often means that policy, including science policy, is made to meet needs as the citizens perceive them. I hope to bring this perspective to the work of the Forum.

FORUM AFAIRS

Report on the April 2004 Meeting of the APS Council

Philip W. Hammer, Forum Councilor

The Council of the American Physical Society met Friday, April 30, 2004 in Denver, just prior to the APS April Meeting (which was held the first weekend of May). In the following, I will summarize reports and actions from the Council meeting that are most relevant to members of the Forum on Physics and Society.

Membership The APS 2004 Membership is 43,258, up from 42,830 in 2003 and a five-year high. The membership of the Forum is 4,624, also a five-year high. The Forum on Physics and Society is the third most popular APS membership unit (10.69% of the membership), after the Forum on Industrial and Applied Physics (12.55%) and the Condensed Matter Physics Division (12.51%).

POPA In the aftermath of the high profile ethical scandals in the physics community, the APS Panel on Public Affairs formed an Ethics Subcommittee that was tasked with surveying the APS membership and examining the range of ethical issues at play in physics. Results from the survey motivated POPA to recommend a statement for Council consideration:

04.1 STATEMENT ON TREATMENT OF SUBORDINATES

(Adopted by Council on April 30, 2004)

Subordinates should be treated with respect and with concern for their well-being. Supervisors have the responsibility to facilitate the research, educational, and professional development of subordinates, to provide a safe, supportive working environment and fair compensation, and to promote the timely advance of graduate students and young researchers to the next stage of career development. In addition, supervisors should ensure that subordinates know how to appeal decisions without fear of retribution.

Contributions of subordinates should be properly acknowledged in publications, presentations, and performance appraisals. In particular, subordinates who have made significant contributions to the concept, design, execution, or interpretation of a research study should be afforded the opportunity of authorship of resulting publications, consistent with APS Guidelines for Professional Conduct.

Supervisors and/or other senior scientists should not be listed on papers of subordinates unless they have also contributed significantly to the concept, design, execution or interpretation of the research study.

Mentoring of students, postdoctoral researchers, and employees with respect to intellectual development, professional and ethical standards, and career guidance, is a core responsibility for supervisors. Periodic communication of constructive performance appraisals is essential.

These guidelines apply equally for subordinates in permanent positions and for those in temporary or visiting positions.

POPA also issued two reports, one on the hydrogen economy and the other on the modern pit facility. These reports, as well as all other POPA reports can be found at: http://www.aps.org/public_affairs/popa/reports/index.cfm.

President's Report APS President Helen Quinn reported on the major initiative of her tenure, namely, long-range planning for the 5-10 year future of APS. The long-range planning will be organized along the major activities of the APS, such as publishing, education, public affairs, meetings, international issues, and committees.

Treasurer's Report The financial state of the APS remains strong, with $40.5 million in revenue and $40.0 million in expenses in 2003.

International Affairs APS has appointed a new director of its Office of International Affairs, Amy Flatten, who replaces Irving Lerch. Flatten reported on the upcoming World Conference on Physics and Sustainable Development, which will be held in late 2005. The conference will have four themes: economic development, health, education, and energy and environment.

The APS Office of International Affairs has also been working to reform post-9/11 restrictions on visas for foreign students and scientists.

Publisher's Report As an interesting point of trivia, the APS publisher, Martin Blume, pointed out that the total lifetime run of Physical Review, if stacked, would make a tower of paper 400 feet tall. The 2003 publishing year contributed 17 feet to the pile. Blume noted that APS will lower its institutional subscription prices in 2005.

Office of Public Affairs Mike Lubell of the Office of Public Affairs reported on the extensive public affairs activities of the APS. The federal budget for research remains the single biggest issue for Lubell and his team. Besides lobbying Congress, APS plays a leadership role in various coalitions organized to impress upon policy makers the importance of research funding. For example, APS is involved in the Energy Sciences Coalition; the K-12 Science, Technology, Engineering, & Mathematics Education Coalition; the Coalition for National Science Funding; and the Coalition for National Security Research. One recently-formed such coalition is the Task Force on the Future of American Innovation, which is joint effort of industry, academia, and professional societies. This group has been publishing ads and op-eds targeted at Congress.

The APS Council will hold its next meeting in November, in conjunction with the Division of Fluid Dynamics meeting.

Philip W. Hammer
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ARTICLES

Teaching About Nuclear Weapons

(Adapted from AAPT Talk, August 3, 2004)

Michael May

With nuclear weapons, there is no effective defense. As a result, unless or until universal disarmament can be achieved, arming to prevent war can only mean nuclear deterrence. The US and the Soviet Union overdid deterrence by a large factor in my estimation, but the general view is that it seemed to work in that particular situation. The key assumption of nuclear deterrence is that the prospect of a single weapon dropped on a single city makes any war of conquest unattractive. Equally important is that the inevitable devastation was obvious to all ahead of time, so that the usual demagogic arguments for war failed and for the most part were not made.

No one pretends that what I have just said about nuclear deterrence is the whole story. For one thing, there are many traps and dangers in the actual practice of nuclear deterrence. What is to be done, for instance, about challenges that don't directly involve the risk of nuclear war but might do so down the line? There were plenty of such challenges during the Cold War, in Korea, in Berlin, in Cuba, and in Israel.

For another thing, with nuclear weapons as with any other weapon, arming itself causes insecurity. Arms control has been a partial answer for nuclear weapons, unlike any other weapon. The reason is not hard to discern: it doesn't really matter if one side has one thousand nuclear weapons and the other has two thousand. Both sides are going to disappear if they are used anyway. As a result, the argument for cheating or escaping out of an arms control agreement is much weaker.

A third problem is the one I personally started out with. Planning new ways to kill people, no matter how disguised in high policy language is at least morally questionable if not worse. Back in 1983, the US Conference of Catholic Bishops came up with a statement on nuclear deterrence that did not quite condemn it as a temporary measure, though it condemned it as a permanent basis for policy. Unfortunately it has become just such a permanent basis. Other organizations, religious and secular, have similarly tried to come up with some moral stand that would be realistic in the short-term and yet in keeping with morality and good sense in the longer term, without notable success.

The best thing that came out of those efforts has been a reminder that peace is a positive task to work on. Although arms control is useful, peace is not built by doing away with some number of weapons: weapons can easily be rebuilt in times of stress, leading to even more dangerous situations than we have now. Peace is built through the positive incentives and institutions that cause people to prefer it to war. Nuclear issues have the advantage of making the long run a little clearer than it usually is. You can get a little more of a hearing when you point out that nuclear weapons could explode in your neighborhood than when you point out that our consumption patterns are likely to lead to our extinction for instance, especially since September 11.

First of all, there is no way to deal with the policy and the moral issues without understanding the technical background, at least to the extent that (as I tell students), the politicians representing them, their staff, and the executive leading private companies involved must understand them. The technical knowledge is essential in itself and it also provides a common basis for broader discussion.There are a few major topics under the heading of nuclear issues, and each has an underlying technical component. The dangers are nuclear terrorism, launch of a nuclear weapon owing to warning system failure, and nuclear war, in any of several forms. The positive side includes nuclear energy if it is done right, nuclear medicine and industrial applications.

Probably the most likely form of nuclear terrorism is a dirty bomb, or radioactive release device in the current lingo. There are millions of radioactive sources, of which a few hundred thousands around the world could constitute a real danger. Hundreds or more are lost every year. Dispersing a harmful quantity of radioactive agent into high explosive is not the easiest job in the world, but there doesn't have to be a lot of radioactivity in order to cause problems. The major problem is not immediate radiation casualties but cleanup. Understanding why this is so leads to a discussion of what and where radioactivity is and how it harms us in enough quantity. It also leads to a discussion of standards: whether EPA standards would be appropriate in response to a dirty bomb attack, what problems responders and authorities face in the coordination exercises they do to get ready and would face in case of a real attack. These problems range from when and where to evacuate and when to go back, all the way to how to provide disposal for large amounts of contaminated materials. We ran into those problems in working on the Topoff 2 coordination exercise last year, which assumed that a dirty bomb had gone off in Seattle.

Nuclear terrorism can also take the form of attack on a nuclear facility, such as a reactor, a spent fuel pool, or one of the very large fixed hospital radiation facility. Those are very hard targets to hit, which can be demonstrated readily, but that in turn leads to discussions of insider threats and personnel assurance, which constitute the main threat.

Potentially most disastrous, of course, and also less likely, at least we hope, would be a nuclear explosion. A numerical understanding of what the kill radii and the fallout patterns are can lead to an evaluation of suitable policies better than the TV specials that could be seen as propaganda by the visually sophisticated students of today. The other essential technical understanding is about the materials needed to make a nuclear weapon, the plutonium and highly enriched uranium. Many thousands of tons of these materials exist, often under poor or unknown security in states where the US has little access and it takes only a few kilograms to make a weapon. The material is most accessible in the excess weapon stockpiles, but there is also plenty buried in the currently highly radioactive civilian spent nuclear fuel and some still in research reactors around the world.

This technical background leads to the most serious security issues of today:

- safeguarding nuclear weapons materials,
- eliminating the nuclear black market,
- reducing US and Russian stockpiles,
- preventing nuclear proliferation
- getting away from the hair-trigger nuclear posture that the major nuclear powers still have and that relies, at least in the Russian case, on an inadequate warning system that has failed before.

It also leads to the need for an understanding of risk as the product of likelihood and consequences, and what is to be done when neither is well known.

These issues bring up both terrorism and war, state actions and non-state actions. A lot of work has been done on all of them. Reviewing this work, from the non-proliferation regime, its achievements and problems, to the Nunn-Lugar programs, to the ongoing discussions with Iran and North Korea, to the recent proposals of President Bush and IAEA Director General ElBaradei aimed at enforcing non-proliferation and breaking any link between terrorists and state-owned nuclear weapons, these things constitute the core of any course on nuclear issues.

These methods seem legalistic but today we face much more difficult situations than Iraq. We don't have good military options to prevent proliferation in Iran or nuclear buildup in North Korea or for securing Pakistan's nuclear weapons, let alone the dangerous materials in the former Soviet Union. The non-military tools we have with these countries and also with allies, such as Taiwan and other East Asian countries who may want nuclear weapons if North Korea gets them, take a while to implement and are subject to the vagaries of the world situation. This is not a problem that is going to go away.

These problems have been worked on for many years and none has been solved. Since we are dealing with our survival or at least the potential for grave damage, the question will come up as to why this is so. Senator Nunn, speaking of the programs to secure nuclear weapon materials in the former Soviet Union that he helped start, recently asked about the ongoing delays and funding shortages: "If this is not the most important security program we have, what is more important? And, if this is the most important, why is it going to take twenty years to get it done?" Working through the answers to that question is among the best thing we do with students. There are some immediate answers. One is narrow bureaucratic interest on all sides. Another is the very size of some of the problems, such as controlling radioactive sources worldwide, or securing shipping containers of which millions come into and out of the US and other countries every year. Part of our nuclear issues seminar is a field trip for students to see what research is being done on the problem of detecting highly enriched uranium or plutonium in a 40-foot shipping container. Still a third obstacle is that countries such as Pakistan, Israel, Iran and North Korea genuinely and for good reasons view themselves as threatened, either or both by their neighbors or the US.

That leads to a couple of more general lessons for discussion. One is that most of the time most people will do business as usual. That means the only way to deal with the dangers we face is for business as usual practices to become adequate. In many of the cases we are talking about, they are not, just as the US intelligence system was not adequate to the dangers of terrorism, and for similar reasons. Emergency actions can be taken if the motivation is sufficient, but business as usual practices are entrenched and very hard to change. Einstein famously said in 1946, unless we change our modes of thinking, we will drift toward unparalleled catastrophe. Drifting is the right word, and we may indeed be so drifting.

Another observation is that, while nothing concentrates the mind as the prospect of being hanged, the memory that we or our institutions did something wrong seems to pass quickly while the memory of grievances, real or imagined seems to last forever, in part because it is cultivated by some politicians, The United Nations was created after two world wars, two nuclear bombings of cities, and a horrible history of massacres and repressions, yet it was not supported well enough to prevent many bloody subsequent wars. On the other hand, after the Soviet Union got the bomb, talk of pre-emptive nuclear war ceased and nuclear deterrence held sway for the remainder of the Cold War. The nuclear hangman was perceived to be at hand. Today, terrorism-relevant information is said to flow more easily now through the maze of the intelligence organizations, but reforming the organizations themselves remains a distant goal. The Bush proposals for counter-proliferation outlined above came after the public surfacing of the AQ Khan nuclear black market. Some actions have been taken, notably Senate ratification of the additional protocol for safeguarding nuclear activities and a UN resolution criminalizing nuclear trade that could lead to proliferation. But a decade-long sustained effort is needed to accomplish the rest.

This type of discussion is a necessary part of teaching about nuclear weapons. It leads far from the technical points briefly noted above, but it must be based on both those technical points and the actual history of what people and countries did in response to the nuclear threat. There is a pattern as to why states obtained or refrained from obtaining nuclear weapons. It is made clear by looking at that history. Insecurity and fear are the dominant motivation. Prestige and influence are next, but there would be no prestige or influence associated with nuclear weapons if nuclear deterrence, which the US and the Soviet Union pioneered, had not demonstrated its effectiveness, at least within the context of the Cold War. Biological and chemical weapons, for which there are defenses and which have not proven themselves as deterrents, possess no such prestige.

From that pattern, another observation emerges. Today, a country like Malaysia can, however unwittingly, export key centrifuge components as part of a nuclear black market ring. Isolated, poor countries like North Korea and earlier South Africa can make nuclear weapons. Yet, most of the measures we have looked at are in the nature of limitations or prohibitions on the tools and technologies needed to make the weapons, supply-side measures in other words. Supply-side measures are bumps on the road nowadays, useful, even necessary, but not enough. Somehow, the demand for nuclear weapons must abate, in the regions that now concern us as it seems to have in regions like say Scandinavia What are the features of countries that seem to have no demand for nuclear weapons although they have the capability? Does the world have to change to be like them before the proliferation problem and with it the terrorism problem is solved? Nuclear terrorists need a state to cooperate or at least shelter them.

One more observation: in the sixties, I gave occasional talks on nuclear weapons at universities. There were often demonstrators in the audience: I would be invited to my own war-crimes trial, for instance. But on the whole most in the audience were willing to engage with the subject. I was director of the Livermore laboratory at the time, and one of my favorite ways to begin was with the question, "Who should work on nuclear weapons?" Then I would list all the answers I could think of on the board: no one, not the US, no one but the US, only the Permanent Five members of the UN Security Council, in any case not the University of California, where I often spoke, or on the contrary only the University or similar non-profits, etc, I would invite the audience to comment on their choice or make a different one. Of course, there was no good choice that could be put into practice at the time, though there were better and worse choices. I think we have a better opportunity now and I think we are not taking it, but that is just my opinion.

My concluding observation is that there is no moral or ethical solution or approach to these problems that is not based on an understanding of the details, both human and technical. Anything else, any a priori choice is at bottom fraudulent. That is the best argument for continuing to teach and learn about these matters of course.

There are many opportunities to do that, at least with regards to terrorism. Courses in schools and universities are only some of them. We have held meetings and a workshop bringing together first responders, such as police, firemen, emergency medical people, media people and local officials with scientists who have a background on one or another aspect of the terrorism question. It is usually welcome, although everyone has a demanding day job to do as well. We have participated in critiquing coordination exercises for terrorism response and in other such activities. Education at the grass roots level on all the questions I outlined and more is essential if the effects of an attack are going to be alleviated.

It is more difficult to educate at the level where decisions relevant to nuclear proliferation, counter-and non-proliferation, and nuclear armaments and arms control are made. The present decision-makers seem to be isolated from constructive alternatives. Perhaps the best we can do here, aside from op-ed and similar pieces, is to educate in a realistic manner the people who will make these decisions tomorrow, and to pray that they get the chance. The key to getting credibility with them is realism. Students today grow up in an atmosphere of unrestrained advertising and show business masquerading as political discourse. In my experience they welcome something better and more demanding if they are given some reason to make the effort.

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The Need for Scientific Literacy in a Challenging Era

(Adapted from AAPT Talk at Sacramento, CA August 3, 2004)

Sidney Drell

I have always felt that the scientific community has a special responsibility to be alert to the implications and practical uses of our progress in understanding nature. We bear an obligation to assist society, in its political deliberations, to understand the potential benefits and risks and to shape in beneficial ways the applications of scientific progress for which we are responsible. Though it need not be fulfilled by each individual scientist, this is a moral obligation of the community as a whole, including scientists engaged in basic research and in applied industrial and weapons research and development, and also in teaching science.

Science and technology are so essential a part of modern life that scientific literacy is assuming an importance comparable to the ability to read and write – which are the more familiar domains of literacy. Science belongs in the core of the education curriculum no less than reading, writing, and arithmetic – and not just to train scientists, any more than English courses should focus on training professional writers. Our challenge is to prepare a broad student community to function and contribute as informed citizens equipped to cope with choices and make important decisions that will shape the quality of the human condition in the 21st century. And education does not take place only in the classroom. We must also make use of a wide range of effective outreach channels – both printed and electronic – to reach a larger public.

My talk will consider the role of physicists in issues of national security since that is the area I know best as a result of personal involvement. But clearly science has been critical in establishing the currently high standards of health and living conditions.

Throughout history scientists and engineers have contributed to the military strength and ultimate security of their societies through the development of new technologies for warfare. And throughout history the military and the governmental leaders have called on scientists and engineers to help devise the means to counter or neutralize the technologies developed by adversaries that threaten their national security.

Looking back to the third century B.C., one recalls the legend of Archimedes designing the great catapult to help thwart the Roman siege of Syracuse. That was but one example of a variety of fortifications and instruments of war that he contributed. Perhaps the best known of the great military scientists throughout history is Leonardo da Vinci, who offered to Milan many instruments of war – military bridges, mortars, mines, chariots, catapults, etc. And later Michelangelo spent time as the engineer-in-chief of the fortifications in Florence.

Equally important to their contributions to developing new military technology, the understanding of the laws of nature by scientists and engineers helps them define the limits of what one can expect from technology – existing and prospective – limits which must be understood when governments formulate military plans and national security policy. Nature cannot be coerced to meet unrealistic military goals.

In most of the combatant countries during World War II, there was a total mobilization of scientists into the war effort. In the United States and Britain they tackled many technical problems, from rockets and antisubmarine warfare to operations research. Physicists played an especially important role in collaboration with the military in developing microwave radar and the atomic bomb. And the decisive role of these weapons has been widely chronicled. This collaboration and its achievements formed the foundation for expanded cooperation following World War II.

A new circumstance emerged in the 1950s with the development of the hydrogen bomb. A factor of 10^6 more destructive than previous explosives, with its greatly enhanced energy release from a second, or fusion, stage, the hydrogen bomb meant that science had now created a weapon of such enormous devastating potential that, if used in large numbers in a future conflict, it could threaten the very existence of civilization as we know it. With nuclear weapons, all-out war was no longer an option. Mass destruction would be inevitable. We were presented with a fundamental issue: can civilization survive? As President Eisenhower said in 1956: "We are rapidly getting to the point that no war can be won." Conventional wars can be fought to exhaustion and surrender, but nuclear war can come close to, in his words, "destruction of the enemy and suicide."

New thinking about conflict resolution was urgently called for. It was essential for us to learn how to resolve our dangerous confrontations and to terminate deadly conflicts before they escalated into a nuclear war that nobody wanted and all too few would survive.

When the grim realities and futility of nuclear war finally sank in, nations around the world recognized the necessity of working together to prevent one. With American leadership, they began to cooperate in multi-national diplomatic efforts to reduce the danger and prevent the proliferation of these weapons. Despite some very frightening crises en route, during the darkest days of the Cold War, we have achieved major successes. The spread of nuclear weapons has been limited to no more than a handful of nations, a norm of not using them in conflict has been established, and this norm has lasted 59 years since Hiroshima and Nagasaki. Nuclear weapons have become weapons of last resort. We recognized that their only use was to deter nuclear attack; to send a warning by their very existence, that, if you do it to us or our friends, the response will be the end of you.

This new circumstance, and the growing danger of renewed conflict in the developing Cold War, greatly enhanced the importance of cooperation and understanding between physicists and the military and national policy leaders. A whole raft of new, serious issues had to be explored and understood – not only hydrogen bombs, but additional challenges including worldwide radioactive fallout from nuclear weapon tests above ground, the global effects of large-scale nuclear war, the leap into space with missiles and rockets, and the role of anti-ballistic missile (ABM) systems. It was also important to communicate with Soviet and other international scientific colleagues to develop a mutual understanding of these issues. Not surprisingly physicists, who were responsible for creating nuclear weapons and understood the horrors they could create, played a prominent role in efforts to control them and helping to unite the international community in this effort.

But it is evident that now we are facing new threats in the 21st century, with terrorism and with the spread of advanced technology. We must deal with rogue nations and despots as well as terrorists whose actions are not limited by what we consider the norms of civilized behavior. Moreover it is not clear that deterrence will remain effective in all such cases, particularly for fanatical terrorists. We must also worry about other weapons of mass terror such as biological weapons. As President Bush said: "The gravest danger our nation faces lies at the crossroad of radicalism and technology." The challenge we must address—both technical and strategic—is how to keep these terrible weapons out of the hands of the worst people, and what to do if we fail. As starting point for considering what needs to be done to meet this challenge, it is useful to begin with a brief review of where things stand today.

Today only eight nations are confirmed nuclear weapon states: the United States, United Kingdom, Russia, China, France, India, Pakistan, and Israel, the latter a non-declared nuclear weapon state. The evidence is unclear as regards North Korea, even though North Korea's government wishes the world to believe it has them. Iran has been aggressively building a nuclear infrastructure. This number of nuclear weapons states is considerably smaller than was anticipated when the nuclear Non-Proliferation Treaty, signed in 1968, entered into force in 1970. (President Kennedy in the early 1960's predicted 25 by 2000). And it hasn't grown over the past two decades. This number is even more impressive when on recalls all the nations who flirted with the idea of going nuclear, and those who, in fact, started down the path to nuclear weapons and turned back. [Argentina, Brazil, Taiwan, South Korea, Sweden]. But we are reminded daily by what is happening in North Korea, Iran, and Pakistan, the latter with its extensive nuclear supplier network created by Dr. Abdul Qadeer Khan as well as its precarious arsenal, that the nuclear restraint regime is facing tough challenges. It has to be addressed from all angles: diplomatic, technical, policy, and intelligence.

Thus far the NonProliferation Treat (NPT) been the bulwark in the effort to counter the spread of nuclear technology and weapons to other nations. It was extended into the indefinite future at the United Nations in 1995 at its fifth and final scheduled five-year review. At present it has almost universal support: of the world's 185 nations, all but four have signed on to this Treaty. The four are India and Pakistan, who became nuclear after the treaty entered into force in 1970, Israel, who has never explicitly admitted to being a nuclear power, and North Korea, which recently withdrew (Jan. 2003). Does it still meet our needs of preventing proliferation and keeping the worst weapons from the worst people? Do we need to modify or toughen its restraints? The U.S. and Russian commitment to the Treaty, and to fulfilling their obligations under it, was explicitly affirmed by Presidents Bush and Putin in their Joint Declaration at the Moscow summit in May 2002. It is clear that to sustain and strengthen the non-proliferation regime the leadership and example of the U.S. will be decisive. The cooperation among all nations – non-nuclear as well as nuclear – will also be crucial. We must also recognize and deal with the concerns and basic motivations which drive some countries to seek to become nuclear powers. That requires much more than simply arguing that proliferation is bad for your health.

I will now briefly discuss major physical and technical challenges to the anti-proliferation effort at present. The biggest hurdle for states or terrorist entities, that seek to achieve a nuclear weapons capability is getting their hands on uranium ore, the raw material from which to make the nuclear fuel, or SNM. The ore has to be enriched by isotope separation from 0.7% to 90+% U^{235} for a uranium bomb, or it has to be converted into fuel rods to power a reactor producing Pu^{239}. The most important means for minimizing the risk of such societies acquiring a nuclear weapon is to keep nuclear fuel - U^{235} and Pu^{239} - out of their hands. For those with no uranium ore on their territory, theft or illegal purchase may be the only way to get it. Of particular concern in this regard is the large quantity of nuclear materials and nuclear warheads stored in the former Soviet Union in less than ideal security circumstances.

Their stockpiles are the largest in the world. As reported in 2002 by the Harvard University Project on Managing the Atom, Russia still has hundreds of tons of separated plutonium and of highly enriched uranium, enough fuel for more than 50,000 nuclear warheads, in addition to its approximately 20,000 warheads that already exist. Material is reportedly spread across more than 250 buildings at 50 sites. Warheads are located in more than 60 sites, in more than 160 storage bunkers. This constitutes a very rich treasure for would-be proliferators, emphasizing the importance of cooperative measures to secure them from theft or sale.

With the lifting of the oppressive measures that regulated travel and other aspects of life in the Soviet Union, and the deterioration of Russian security services, there is now a need for better systems of protecting and accounting for their vast stores of nuclear materials that remain as a legacy of the Cold War.

Technology is available to protect this material by installing new security systems, and substantial progress has been made in the former Soviet Union under the Nunn-Lugar CTR program that is funded by the U.S. Congress since 1992 to the tune of very roughly $1B/year. It is an outstanding example of U.S. statecraft. But vulnerabilities still remain. More than half of the nuclear material in the former Soviet Union still remains to be protected by improved security for material protection, control, and accountability; and there is an eager market to get their hands on it. And many border crossings are unprotected.

For those with ore available, the challenge is to prevent them from enriching it or producing Pu.

The May 2002 Bush-Putin Declaration of Moscow that I referred to earlier calls on all nations to strengthen and strictly enforce export controls, interdict illegal transfers, prosecute violators, and tighten border controls to prevent the proliferation of nuclear weapons (and of biological and chemical weapons as well).

This program presents a considerable intelligence challenge, and also a political one, requiring broad international cooperation to monitor such compliance measures; of obvious importance are activities to produce nuclear weapons in a nation that has initiated a serious covert effort to build one. To illustrate what is required, consider a nation that has adequate uranium deposits in its territory as well as the technical-industrial base to produce nuclear weapons indigenously. Let's assume it chooses to build a gaseous centrifuge plant to enrich uranium to fuel a gun-type driven weapon. Technology for gas centrifuge machines is widely available. Such a first generation uranium fission bomb, in a gun-type assembly, was what the U.S. dropped on Hiroshima. No large reactor to produce Pu^{239} is required, nor perfecting the more sophisticated implosion mechanism as needed for a plutonium bomb. Furthermore, it could be deployed with confidence without requiring an underground nuclear explosive test, just as we did with the Hiroshima bomb.

I do not want to imply that building up a functioning nuclear weapons program is a simple task. In spite of all that is now known and is widely available in the public domain about nuclear technology, it still requires a capital investment in the plant and a substantial effort involving large numbers of trained people with specialized engineering and scientific skills (e.g., obtaining and working with maraging steel needed for very rapidly spinning centrifuges). Nevertheless, if a proliferating country wished to conceal a gas centrifuge plant capable of enriching enough uranium to fuel several weapons per year, the challenge would not be insurmountable: the required facility could be contained on a factory floor space of modest size. The energy requirements are low. It would require less than a megawatt of electric power input and could be readily built underground. The large halls at the uranium enrichment facility recently observed at Natanz in Iran – roughly 2 football fields in size – are estimated to be capable of holding over 50,000 centrifuges, enough to fuel a dozen or more uranium bombs per year. For several bombs per year the plant could be proportionally smaller. With current widely available technology it would require perhaps 3,500 gas centrifuges, depending upon their efficiency, to produce fuel for just one primitive enriched uranium weapon in a year (14,000 SWUs). (x10 for 4% U^{235} for 1.3 GW Light Water Reactor)

With more modern gas centrifuge technology, the plant size could be significantly smaller. This emphasizes the importance of monitoring from the very beginning of the construction, together with insisting on authority for on-site challenge inspections once a suspicious activity has been identified. This will almost certainly require mandatory full-scope on-site inspection measures beyond authority that the IAEA has currently over all declared sources and fissile materials for peaceful nuclear activities. It will have to include challenge on-site inspections of undeclared and suspect activities as well, as called for in the Additional Protocol to the NPT that has yet to be acted on by many nations as a requirement for all NPT signatories. That protocol to the NPT, advocated by the Bush Administration and ratified by Congress, will also require in addition to universal acceptance, enforcement powers to deal with cases where a nation refuses to admit or give access to inspectors.

These observations give a picture of the scale of effort and difficulty involved in detecting and/or hiding nuclear production activities. This monitoring problem is a complex one that requires more than just the satellites, or so-called national technical means, circling the earth and sampling all parts of the electromagnetic spectrum from a couple of hundred kilometers up to synchronous orbit. Onsite inspection, and familiarity with the culture and the language, have become the part of the new intelligence challenge. We have a measure of confidence in the ability to meet this challenge based on our experience with Iran and North Korea and the fact that their efforts at covert programs have not succeeded for extended periods of time. But for high confidence in timely detection we will require bringing into effect the Additional Protocol to the NPT strengthened with enforcement authority by IAEA. This presents one of the really hard problems for maintaining a non-proliferation regime in today's world, as illustrated in current discussions with Iran and North Korea.

In addition to the challenge to the non-proliferation regime from nations abroad like North Korea and Iran, as was also the case for Iraq before the Gulf war, there is also an apparent challenge coming from changes in nuclear weapons policy being considered in Washington. Several voices in U.S. official circles have recently proposed that the U.S. consider developing a new generation of low-yield nuclear weapons for use in limited military engagements – particularly against deep underground hardened bunkers. These weapons would be considered more useable in such missions by virtue of the reduced collateral damage they will cause from dispersed radioactive debris. Congress appropriated roughly one-half of the funds requested for studying such weapons in FY 2004; the request for FY2005 is still being debated.

The Bush administration's 2002 Nuclear Posture Review states that a "need may arise to modify, upgrade, or replace portions of the extant nuclear force or develop concepts for follow-on nuclear weapons better suited to the nation's needs." And the Review highlights a specific need for a class of low-yield earth-penetrating nuclear weapons – or so-called "bunker busters" – "to defeat emerging threats such as hard and deeply buried targets (HDBT)" of military interest being built in many countries.

Such a policy would be a rejection of the fundamental proposition underlying deterrence and the non-proliferation regime: that the only purpose of nuclear weapons is as weapons of defensive last resort.

The idea of low-yield more useable nuclear weapons for military missions such as attacking HDBTs needs quantitative evaluation on technical grounds as to their actual military effectiveness. It would be foolish to seriously harm our national security by weakening deterrence and the non-proliferation regime in order to achieve nothing more than marginal military value.

The current interest in the "bunker busters" has been motivated by the growing number of hard and deeply buried facilities being built in a number of countries. Citing recent government studies, the Nuclear Posture Review states that there are some 70 nations with more than 1,000 known or suspected strategic targets, which are used for storing weapons of mass destruction, protecting senior leaders, or executing top-echelon command and control functions. Among the underground targets of most concern are very hardened structures built, at depths of 1,000 feet or more, with reinforced concrete capable of withstanding up to 1,000 atmospheres overpressure.

Destroying such targets requires knowing exactly where they are and then precisely delivering a warhead that can penetrate into the earth without damage before detonating. The warhead must also have a sufficiently large explosive yield to transmit a strong shock. The United States after >1000 tests has already designed and tested a variety of low-yield nuclear devices that could be adapted for delivery in structurally strengthened warheads for destroying underground targets at shallow depths. Recently, it adapted a high-yield weapon, the B61-11 bomb, with yields that exceed a hundred kilotons, in this manner. A key technical challenge is to develop the means to deliver such a bomb intact to depths of 10-20 feet before detonation. Detonation at such depths increases, by a factor of 10-20 relative to a surface burst, the energy of the explosion that is delivered into the ground instead of into the atmosphere. The warhead therefore hits the target – a hardened, buried bunker or tunnel – with a much stronger shock than an identical warhead that is detonated on or above the surface.

Taking into account realistic limits on material strengths, about 50 feet is the maximum depth to which a warhead dropped from the air into dry rock soil could maintain its integrity until detonated. This is true even with impact at supersonic speeds. For the shock to reach down to 1,000 feet with enough strength to destroy a hard target in dry rock, the yield of the warhead must be significantly larger than 100 kilotons, certainly not a low-yield weapon. As to the collateral damage produced by such bunker busters, particularly if used in or near urban settings which can be the preferred locales for hardened underground targets, the blast of even a very "low-yield," one-kiloton earth penetrator would eject vast amounts of radioactive debris, and would be quite devastating in a city. The radioactive contamination from a one-kiloton warhead (just 1/13 the yield of the bomb that destroyed Hiroshima) detonated at a depth of 20-50 feet would eject more than 1 million cubic feet of radioactive debris from a crater about the size of ground zero at the World Trade Center – bigger than a football field. Indeed the Hiroshima bomb was detonated at an altitude of close to 1,900 feet in order to minimize radioactive fallout by not digging any crater. And against really deep targets, yields in the hundreds of kilotons would be required. A nuclear weapon with a yield, Y, capable of destroying a target 1,000 feet underground – a yield well over 100 kilotons – would dig a much larger crater and create a substantially larger amount of radioactive debris. (Dimensions scale roughly as $Y^{1/3}$ and volume and mass of debris closer to Y).

Accuracy is also crucial and made possible by GPS and laser-guidance. But the most difficult challenge for destroying hardened underground targets is the ability to locate, identify, and characterize such targets. The payoff of accuracy in underground target location, not just in delivery of a weapon is enormous. It is also important to find any vulnerable points such as tunnel entrances or air ducts.

Nuclear weapons are also of limited value against biological and chemical weapons stored in underground bunkers. When detonated underground their effective range in destroying the deadly effects of pathogens and gases is limited by the fact that their blast effects extend beyond the area of very high temperatures and radiation they create for destroying such agents. This area extends not much further than the range of neutrons and prompt gamma rays emitted during the explosion, or only a few meters for a kiloton weapon and increasing only as the cube root for higher yields. Therefore they would be more likely to spread these agents widely, rather than to destroy them completely. As an alternative to destroying such localized HDBTs, the United States should pursue effective means to put them out of business – that is, to functionally defeat them – using conventional forces and tactics. This would required improving the ability to locate and seal off their points of access and exit for equipment, resources, and personnel; and, when possible, to establish area control and denial around them.

Bottom Line: A decision by the world's only superpower to develop and test new, and presumably "more usable," nuclear weapons for new missions as bunker busters would send a clear and negative signal about the non-proliferation regime to the non-nuclear states. If the United States, the strongest nation in the world, concludes that it cannot protect its vital interests without relying on nuclear weapons in limited war situations, such as against deeply buried targets, it would be a clear signal to other nations that nuclear weapons are necessary for their security purposes too. The United States could thereby be dealing a fatal blow to the regime in order to provide itself with a capability of questionable military value.

Beyond the specific technical points I have been making about bunker busters, there are deeper and more difficult policy issues that are challenging this country and other nations: we face the prospect of not only rogue nations, but generally very bad, dangerous people, including fanatical and often suicidal terrorists, attempting to get their hands on nuclear and biological weapons capable of devastating destruction and terror. What can we do to make sure that if the worst people do succeed in getting their hands on the worst weapons by theft, illegal purchase, or any other failure of our anti-proliferation efforts, that they will never to able to threaten to use them against us?

Against such individuals whose behavior is not restrained by the norms of civilized behavior, deterrence and containment as we have known them thus far may not be adequate, and a more aggressive policy is required. This is not an idle theoretical question but rather an issue very much on the agenda, explicitly raised in our most recent national security strategy documents. To meet this challenge the United States has adopted a policy of taking anticipatory action to defend itself against emerging threats "before they are fully formed"; that is, we will take preventive military action before the existence of an established threat. But we have to recognize that the actual implementation of such an aggressive policy of preventive military action comes with serious risks and raises tough new questions. Against whom, in particular, and when and how, should military force be applied against emerging but not yet fully developed threats of nuclear or biological weapons?

Preventive military action requires exquisite intelligence to evaluate the danger accurately and to identify the critical targets correctly. Our current difficulties and debates about U.S. policy in the mid-East, however you view the choice that the U.S. has made to initiate war against Iraq, are clear evidence of the difficulties of taking such actions. Most decisions to initiate preventive action have to be made even though there may be big uncertainties, as well as gaps and wrong information on essential facts, a circumstance that may result in divided support and challenges to the legitimacy of the mission, both at home and abroad, if not its outright failure. That is all the more reason to exhaust all possible avenues of diplomacy before relying on force, when it is deemed necessary, as a last resort.

To be sure, it is a very tough order and a frustrating ordeal to engage in patient, multi-national diplomacy with rogue nations that are bent on joining the nuclear club. And it is even more daunting to get at the roots of what generates fanatical destructive behavior in terrorists. Furthermore changing such behavior patterns takes a lot of time as well as effort. In the meantime we have to pursue practical measures that can be effective in the short term in keeping evil despots and suicidal terrorists from being able to threaten us with nuclear and biological weapons of mass destruction and terror. The terrorist strikes of 9/11 and just two months ago in Spain are warning enough of this need.

We have several examples from recent history that illustrate conditions under which military force, or the threat of preventive or preemptive action, can be effective: 1) the likelihood of successful retaliation by the potential proliferant is low; 2) the proliferant is viewed by large parts of the international community as a threat to its neighbors; 3) peaceful means of blocking nuclear or biological weapons programs has failed or seems likely to fail. All three conditions are almost certainly necessary if a proposed use of military force is to gain the broadest possible support, not only for the military action itself but also for the follow-through, economic and otherwise. However, the simultaneous existence of all three conditions is the exception rather than the rule. As evidence, recall cases where not all three conditions existed, and military force or the threat of force was not credible and was not brought into play. They include the Soviet Union in the 1950s as it tested and began to deploy nuclear weapons, and China, when it began to move toward a nuclear weapons capability in the 1960s. There were influential voices in the United States that spoke out for preventive war against the Soviet Union in the 1950s, fearing that a Soviet nuclear arsenal would prove devastating for American's position in the world and for the American homeland itself. A similar discussion took place at high levels of the American and Soviet governments during the Kennedy administration when China was seen to be nearing a nuclear weapons capability. The discussion led nowhere, another example of the lack of utility of military force under the circumstances then existing.

In order to halt North Korea's nuclear programs, it will undoubtedly be necessary to negotiate a non-use of force commitment between the United States and North Korea in the context of a freeze and dismantlement of all North Korea's nuclear weapons programs. The Clinton Administration's Agreed Framework of 1994 froze their nuclear reactor and reprocessing activities in return for promises of power for civilian needs and limited economic aid. We now would insist on the return of IAEA inspectors with the authority to inspect the elements of a gas centrifuge facility for enriching uranium components, which North Korea has recently been acquiring in violation of the Agreed Framework, and setting a firm schedule for removing the plutonium, including all spent fuel rods from North Korea, and dismantling its nuclear weapons facilities and program.

The North Korean leadership is primarily interested in survival and seems to be aware that economic changes will be necessary for that to happen. Unless the leadership becomes firmly committed to that route and convinced that it will be safe to pursue it – or the present government collapses under the weight of its domestic failures and abuses – the leadership will persist in its development of a nuclear weapons capability. Crisis will follow crisis until military action, or acceptance of North Korea as a nuclear weapons state, are the only alternatives.

A broad program of economic cooperation involving North Korea must proceed on a multilateral basis. And security guarantees should ultimately include North Korea's neighbors – South Korea, above all. Since North Korea poses a threat to its neighbors, guarantees must be a two-way street.

Some issues probably can only be resolved through trilateral talks between the United States, South and North Korea aimed at revising the system created by the armistice agreement of 1953. Most likely Russia, China, and Japan will also play a prominent role in the diplomatic steps leading to a peace treaty and to other obligations undertaken among the parties, although not all the obligations will be of concern to every party.

Are the U.S. Congress and the American public ready for this? With presidential leadership, perhaps so, especially since the alternative very likely will be not only a nuclear-armed North Korea but also the entry of Japan, South Korea, and perhaps Taiwan into the ranks of nuclear-weapon states. This would affect China, which would affect India, which would affect Pakistan. An Asian arms race rivaling the Cold War's U.S.-Soviet nuclear arms race could be the result.

In addition to continuing the moratorium on underground nuclear explosive testing we should work toward bringing a Comprehensive Test Ban Treaty into force.

Many nations signed on to the indefinite extension of the NPT in 1995 on the explicit condition that the nuclear powers would cease all nuclear-yield testing. A U.S. decision to terminate our moratorium since 1992 and to resume testing to produce new nuclear weapons would therefore dramatically undermine the NPT. Conversely, a U.S. decision to ratify the CTBT that it signed in 1996 and lead the effort to bring the treaty into force would be an effective way of strengthening the NPT and, through it, worldwide anti-proliferation efforts.

All U.S. allies in NATO, including Great Britain, Germany, and France, have signed and ratified the CTBT, as have Japan and Russia. Israel has signed the CTBT and is participating energetically in the work of setting up a verification system. Others, including China, have indicated they will work to bring the treaty into force once the United States has ratified it. Currently 32 of the 44 nations that have built nuclear reactors, the so-called "nuclear-capable states" that must ratify the treaty for it to enter into force, have done so. *In toto,* 112 states have now ratified and 171 have signed. It is time for the U.S. to reconsider the issue of ratifying the CTBT. The White House and the Senate should enter into a serious debate to clarify the underlying issues, both the concerns and opportunities. This debate was not adequately joined in 1999 when the CTBT first came before the Senate for its advice and consent to ratification, and regrettably the Bush administration has thus far refused to reopen the question.

Why is the United States reluctant? In addition to the dubious need to develop "concepts for follow-on nuclear weapons better suited to the nation's needs," including nuclear earth penetrators against HDBTs, opponents of the CTBT have raised two questions: (1) "How can we be sure that many years ahead, we will not need to resume yield testing in order to rebuild the stockpile?"; and (2) "How can we monitor compliance by other CTBT signatories to standards consistent with U.S. national security?"

The answer to the first question is that total certainty can never be achieved. But the United States can be assured that the CTBT is consistent with the ability to retain high confidence in the reliability of its existing nuclear force for decades. This conclusion has been demonstrated by a number of detailed technical analyses. In 1995 a team of JASON scientists working with colleagues from the weapons community, including technical leaders involved in creating the current nuclear arsenal (one of whom, Seymour Sack of Livermore, is a recipient of this year's Fermi Award), reached this finding. This conclusion requires the U.S. to have a well-supported, science-based stewardship and maintenance program, as well as a capability to remanufacture warheads as needed. That determination was crucial to the decision by the United States to negotiate the CTBT and sign it in 1996. Most recently, in August 2002, a panel of the National Academy of Sciences reaffirmed this conclusion. And in 2001 so did a government sponsored study, led by General Shalikashvili, former Chairman of the Joint Chiefs that addressed strategic as well as technical issues.

In his letter to the President, General Shalikashvili affirmed that the CTBT "is a very important part of global non-proliferation efforts and is compatible with keeping a safe, reliable U.S. nuclear deterrent."

Concerning the question of compliance, there is a broad agreement that the United States could monitor CTBT compliance to standards consistent with its national security. Based on its technical analysis, the National Academy of Sciences study group concluded that

> The worst-case scenario under a no-CTBT regime poses far bigger threats to U.S. security – 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.

By acquiring challenge rights to check out data initially derived from remote sensors, and by conducting short-notice, on-site inspections of suspicious events, the verification system when fully implemented under a CTBT, becomes more robust and difficult to evade. A further strengthening of the sensitivity of the CTBT to detect covert, treaty-violating activities could be negotiated by adding appropriate bilateral transparency and confidence-building measures with the other nuclear powers, Russia and China in particular. These would permit on-site sensors to be introduced at their instrumented test sites to monitor for signals – seismic and radiological – from possible underground tests that are banned by the CTBT. The Bush administration should clearly state its willingness to initiate such an arrangement, reciprocally with the Russians, at Novaya Zemlya and the Nevada Test Site.

The CTBT does not increase the requirements for the U.S. to monitor and identify underground testing. The U.S. will want all information on testing activities, with or without the treaty. It does, however, add to the difficulties for a country to evade the treaty not only by strengthening the system but also by adding the inspection rights. Furthermore, given that the United States has the most advanced and sophisticated diagnostic, analytical, experimental, and computation facilities, it is in a stronger position than other nations to maintain a deterrent under a test ban. As General Shalikashvili concluded in his study, "I believe that an objective and thorough net assessment shows convincingly that U.S. interests, as well as those of friends and allies, will be served by the Treaty's entry into force."

Another diplomatic tool would be to pursue multilateral cooperation on bringing early-warning and defensive systems into force that can help build a stronger anti-proliferation coalition. This has been talked about between the U.S. and Russia, as well as more broadly, but it now calls for more aggressive action to get anywhere.

To conclude we have to ask: It is possible for the United States and its fiends to agree on criteria compelling action against terrorists that are attempting to acquire nuclear capabilities, or against the states that are harboring them? The experience at the United Nations leading up to the invasion of Iraq shows how difficult that challenge will be. There is a need to restore and strengthen the international consensus that nuclear proliferation should be prevented, and it must begin with building a consensus within the UN Security Council on what to do about terrorists and their access to nuclear weapons.

One of the reasons that the United States is not enjoying the broad international support it should have for the campaign against the linked problems of terrorism and proliferation of nuclear weapons is the perception that unilateral preventive (elective) war has become the dominant strain in American thinking about the problem. To change that perception the U.S. will have to resort to a continuum of means, keyed on patient, determined diplomacy supported by coercion and force when required, in order to deal with the threats posed by such weapons against the security of the United States and its allies, and indeed against civilization.

We have begun to do this. It has returned to a multilateral approach to dealing with North Korea and Iran on the diplomatic front. Such a commitment is also required to help heal scars of the cut and thrust of our approach to Iraq and to get on with our anti-proliferation efforts.

The urgency for such a commitment to deal with the nuclear threat has been expressed powerfully and dramatically by Father Bryan Hehir, former dean of Harvard Divinity School, in his keynote address on "Ethical Considerations of Living in the Nuclear Age" at a Stanford University conference in 1987:

> For millennia people believed that if anyone had the right to call the ultimate moment of truth, one must name that person God. Since the dawn of the nuclear age we have progressively acquired the capacity to call the ultimate moment of truth and we are not gods. But we must live with what we have created.

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COMMENTARY

POPA Looks at the Hydrogen Initiative and a Proposed Modern Pit Facility

Barbara Goss Levi,

POPA occasionally produces discussion papers on topics currently debated in Congress in order to inform the debate with the perspectives of physicists working in the relevant issue areas (see www.aps.org/public_affairs/index.cfm). In the past year, POPA members have produced such papers on two different topics.

The hydrogen initiative.

The first report dealt with the multi-year $1.2 billion Hydrogen Initiative proposed in 2003 by President Bush to reduce the nation's dependence on foreign oil through the production of hydrogen fuel and a hydrogen-fueled car. What would be the appropriate allocation of such funds?

The main message of the POPA report is that "major scientific breakthroughs are required for the Hydrogen Initiative to succeed. Basic science must have greater emphasis both in planning and in the research program."

The concluding statement of the POPA report also suggests that "the Hydrogen Technical Advisory Committee … include members who are deeply familiar with the core basic science problems. 'Bridge' technologies should be given greater attention. And, the Hydrogen Initiative should not displace research into promising energy efficiency and renewable energy areas."

The report advised against rushing into demonstration projects: Demonstration projects "will only benefit the overall program when a sufficient knowledge base exists." It also advocated that "Principal-Investigator research . . . be increased. And, PI research should be complemented with competitively-bid, peer-reviewed multidisciplinary research centers that carry out basic research in the key research areas of production, storage and use."

APS Associate Director of Public Affairs, Francis Slakey, reports that several recent actions of Congress are consistent with these recommendations. In particular, the House Appropriations Bill recently reduced funding for applied research and demonstration projects for the hydrogen initiative and fully funded increases for basic research at DOE Office of Science for hydrogen research. Also, while the Bill is not unsupportive of hydrogen research centers, it required that the funding for the proposed centers be "competitively bid" and peer reviewed - no earmarks.

A Modern Pit Facility?

In the past year there has been some pressure on Congress to fund the development of a Modern Pit Facility (MPF) to produce the cores for nuclear weapons. Even if the US nuclear arsenal does not grow, existing cores will need to be replaced as they age. The only US pit manufacturing facility was shut down in 1989, and the National Nuclear Security Administration (NNSA) recently reestablished a limited capability to produce pits at the Los Alamos National Laboratory. The NNSA has proposed an additional Modern Pit Facility (MPF) that would have a much larger capacity.

A subset of POPA examined the technical issues associated with the MPF because such a large investment in permanent infrastructure is a significant commitment of resources in the overall stewardship program. Their main message is to defer a decision on the MPF:

> "There are several technical issues to address before proceeding with site selection or committing to an MPF design. These decisions should be deferred until Congress can more thoroughly assess the MPF and various alternatives while supporting an enhanced research program on plutonium aging. In particular, in 2006, a milestone will be reached in an experiment to estimate the minimum pit lifetime, the result of which will help inform production needs. Further, pit production assessments must be informed by clearer evaluations of future nuclear force structure."

Slakey reports a positive reception of this message on the Hill. The Senate Armed Services Committee recently suspended 50% of MPF funding pending an assessment of pit production requirements. And they contracted with JASON to do a study on plutonium aging. Furthermore, Slakey says, the House Energy and Water Committee suspended all funding for MPF pending the results of the accelerated aging experiment.

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BOX 1: The Hydrogen Initiative: Executive Summary

In 2003, President Bush announced a multi-year $1.2 billion Hydrogen Initiative intended to reduce the nation's dependence on foreign oil through the production of hydrogen fuel and a hydrogen-fueled car. The Initiative has envisioned the competitive use of hydrogen in commercial transportation by the year 2020.

Currently, the US hydrogen industry produces 9,000,000 tons of hydrogen per year. Several hydrogen-fueling stations are scheduled to open this year. And, several models of hydrogen-fueled cars have been demonstrated.

Unfortunately, none of the current technologies are competitive options for the consumer. The most promising hydrogen-engine technologies require factors of 10 to 100 improvements in cost or performance in order to be competitive. Further, hydrogen cannot simply be extracted from the air, ground or water – it must be produced. Yet, as the Secretary of Energy has stated, current hydrogen production methods are four times more expensive than gasoline. Finally, no material exists to construct a hydrogen fuel tank that meets the consumer benchmarks. A new material must be developed.
These are enormous performance gaps. Incremental improvements to existing technologies are not sufficient to close all the gaps. For the Hydrogen Initiative to succeed, major scientific breakthroughs are needed.

Basic science must have greater emphasis both in planning and in the research program. The Hydrogen Technical Advisory Committee should include members of the basic research community who are familiar with the relevant science problems. Further, given the multidisciplinary nature of the scientific problems involved, principal-investigator funded research should be complemented with the creation of several peer-reviewed, competitively bid, Research Centers that focus on the relevant research problems in hydrogen production, storage and use.

In the event that the timeline for hydrogen vehicles slips beyond 2020, there will be greater need for technologies that serve as a so-called “bridge” between the current fossil-fuel economy and any future hydrogen economy. Increasing the focus on basic science and engineering that advances such technologies would serve as a sensible hedge and at the same time maintain the development of technologies that show clear short-term promise. Similarly, the Hydrogen Initiative must not displace research into promising energy efficiency and renewable energy areas.

BOX 2: The Modern Pit Facility: Executive Summary

Plutonium “pits” are the cores of modern nuclear weapons. In order to ensure that the U.S. nuclear arsenal is safe and reliable, plutonium pits are closely monitored for any deterioration due to aging.

The average age of plutonium pits in the U.S. arsenal is 20 years with the oldest being about 26 years old. The *minimum* pit lifetime is currently estimated to be 45 to 60 years, based largely on the modest changes observed in key properties of plutonium samples that are 40 years old.

The pits in the current nuclear weapons stockpile were manufactured at a facility that was shut down in 1989. The National Nuclear Security Administration (NNSA) recently reestablished a limited capability to produce pits at the Los Alamos National Laboratory. The NNSA has proposed an additional Modern Pit Facility (MPF) that could produce, depending on the final design, either 125, 250 or 450 pits per year in single-shift operation, beginning in 2020.

Recent Congressional hearings and associated testimony have indicated that a MPF could be a major budget item for the NNSA. The APS Panel examined the technical issues associated with the MPF because such a large investment in permanent infrastructure is a demanding commitment of resources in the stewardship program.

The APS Panel concluded that there is insufficient technical reason to commit to a site or design for a MPF at this time. Deferring such decisions until at least 2006, the date that the NNSA initially proposed in evaluating the facility’s environmental impact, would allow Congress to more thoroughly consider key issues that could significantly affect overall decisions regarding an MPF:

• Pit facility design and site selection should not proceed until there are more precise estimates of future nuclear force structure.

• Site and design decisions should be deferred while the NNSA enhances the research program on plutonium aging. In particular, an experiment is underway which by 2006 will help determine whether pits can be expected to have a minimum lifetime of 60 years. With a 60-year minimum lifetime, the earliest that a pit might need to be replaced is 2038, and there may be no need to commit to a MPF for 15 more years.

• The various production options should be more thoroughly assessed. In particular, the cost and benefits should be evaluated for a small-scale production facility – capable of producing 50 to 80 pits a year in single-shift operation - that has the capability of a modular enhancement to larger production if necessary.

Skewness of Federal R & D Funding

Jeffrey Marque

The AIP's FYI #73, dated June 9, 2004 and authored by Richard M. Jones, describes a report by the Science & Technology Policy Institute for the National Science Foundation. Entitled *Vital Assets*, the report gives comprehensive data on Federal funds for the conduct of research and development (R&D) in every state of the U.S. The report is available at http://www.rand.org/publications/MR/MR1824/

I found the report to be so overwhelmingly rich with data that I had to rely on the analysis and discussions within the report to make sense of the data. Some of the findings of the report are remarkable, and some quite disturbing:

1) In FY2002, 45% of all federal R&D funds provided to universities and colleges went directly to medical schools. The top ten states in overall ranking for federal funding in FY2002 have 48% of the nation's medical schools. In FY2002, the fractions of federal R&D funds received by Vermont, Connecticut, and Missouri that went to their medical schools were, respectively, 74%, 72%, and 69% (!!)

2) In the current funding profile, approximately 2/3 of federal funds going to universities and colleges for the conduct of R&D is focused on life science. Only the remainder is for physics, chemistry, geology, engineering, energy, environmental science, education, homeland security, ,etc.

3) It is a myth that all federal R&D funds are conveyed via peer-reviewed project grants.

4) Only the universities and colleges in California, New York, Pennsylvania, and Texas were successful in obtaining significant amounts of R&D monies from all the major federal R&D fund sources. The remaining states tend to specialize.

5) Even if we ignore all of the R&D funds going to the medical schools, Health and Human Services remains the largest provider of R&D to the nation's universities and colleges. Next, in order of size of funding, come NSF, DOD, NASA, DOE, and USDA. Smaller amounts are from agencies with some of whose acronyms I am not familiar: DOC, DED, HUD, DOI, DOL, DOT, DVA, EPA, NRC, and SSA.

Twelve universities and colleges receiving federal R&D funds in FY2002 ranked in the top 20 regardless of whether or not analysis included R&D funds going to medical schools. Eighty institutions of higher education ranked among the top 100 in FY2002 independent of medical school funding. These numbers suggest that federally supported R&D is concentrated at only a few of the nation's schools. "…while many of the nation's universities and colleges received some federal R&D funds in FY2002, the majority of federally supported R&D activities were highly concentrated in only a few of them."

There is also a concentration of funding within the medical schools. The top ten (out of 126) medical schools (in terms of federal funding) received 29% of the funds for *all* the medical schools. The top 20 schools garnered 47% of all the funds distributed to medical schools. So about 1/2 of the money goes to less than 1/6 of the schools.

The FYI mentioned at the beginning of this commentary quotes three questions raised in the report,

"Are biomedical and health care issues so clearly at the top of the nation's agenda that they merit two-thirds of all federal funds provided to universities and colleges for the conduct of R&D?"

"Are other critical national needs that have substantial R&D components (such as environment, energy, homeland security, and education) getting the attention they require?"

"Are science and engineering students at universities and colleges that do not receive a notable share of federal R&D funds receiving a lower-quality education? Are their career opportunities hampered as a result?"

It seems to me that these four questions are largely rhetorical, with the implied answers being, respectively: no, no, yes, and yes.

There is one remark in the report that immediately had the ring of truth to this exhausted reader: "The ways in which one can use the information in this report to look at the distribution of federal R&D funds among the nation's universities and colleges are virtually endless." Yes! And I found the *actual* cuts through the data analyzed in the report to be seemingly endless, and I thus very much appreciated the report's summaries and conclusions.

Having just complained about the endless cuts through the data, it occurred to me while reading the report that there was no analysis of per capita funding among the various states. Thus, for example, I wondered if part of the reason that California received so much funding and South Dakota so relatively little is because California's population is so much greater. A per capita cut through the data might have been useful and may have served to blunt some of the extremes of the state-to-state comparisons.

In these comments, I have by no means covered all the topics in the report. For example, the report goes into considerable detail about the various ways that federal funds are disbursed other than peer-reviewed project grants.

I would summarize by encouraging people to read, or at least peruse, the report for the following reason: The extreme skewing of funding that is described in the report points to a future in which basic science R&D, a critical source of innovation and national security (both military and economic), has dried up. Combined with the trouble that so many excellent foreign scientists are having in their attempts to get visas to come to the U.S., the report gives pause for serious concern about the direction in which science in the U.S. is headed. The wealth of data provided in the report would be very useful to any citizen wanting to communicate with his or her representatives in Washington, D.C. about these issues.

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Threats to American Preeminence in Innovation

Alvin M. Saperstein

The American Institute of Physics Bulletin of Science Policy News, No. 94: July 13, 2004 reports on a Congressional briefing in which speakers warned of threats to America's preeminence in innovation - and thus to our competitive edge in the world. Similar warnings have been voiced in many other public forums. The usual reason given is the declining number of American born and educated students who major in fields of science and technology. New to the list of reasons given is the growing strength (and competition) of foreign scientific and technological universities, research institutes, and business as well as the barriers erected to the importation of foreign scientific-technological scholars and students ever since the 9/ 11 attacks awakened the public to the threat of international terrorism. The usual fixes offered are more money for education and research and more supportive but streamlined governmental policies.

Without denying the importance of these reasons (and fixes) for the projected decline of American preeminence in scientific and technological innovation, I believe that other - more important - factors are operative. Successful innovation - in business, culture, government, and society, as well as in technology - depends upon the critical spirit engendered by science. This critical spirit exists, to some extent, in all societies. But it is a product of the "age of enlightenment", and grew and prospered in Jeffersonian America more markedly than in other contemporary societies. The pervasiveness of that spirit, in America, seems to be waning. To the extent that it is waxing elsewhere, our cultural and economic preeminence is at risk.

Science stands upon two legs: the belief in the reality of a rationally describable world "out there", and the imperative to seek and say maximal truth. Both of these legs are hobbled by the presently prevailing trends in American life: the prevalence of "sound bites", rather than extensive discourse, in all aspects of American life; the ubiquitous exposure of our growing youth to contradictory advertising and "stories" in all of the public media; and the blatant distortion of truth in our political institutions. These all contribute significantly to the demise of scientific competence and interest among our youth (and their respect for science) - and hence of innovation in our future elites.

How is a child to acquire a belief in a unique, rationally operative, real world when constantly presented with mutually exclusive assertions about the world? E.g., the TV (before which he/she spends more time than before any teacher) alternates between saying that "Coke is the best" and "Pepsi is the best" in the advertisements accompanying shows featuring battles between werewolves and space ships. When a portion of school, play, and TV watching time is spent extolling "junk foods" while the health classes describe their ill effects. When the shelves next to the science section in the bookstore or public library are the astrology and psychic shelves? Or when church and family talk about a five-thousand year old Earth while the science teacher mumbles about a five-billion year old home planet?

Certainly we humans have always grown up with competing views of reality thrust at us. But the possibility - the imperative - of the common man manipulating the world around him/her, so as to become familiar with its reality, was always present. (It was from that "common man" - and common experience - that technology and, eventually, science arose.) Increasingly, that manipulation - model building, tinkering, laboring in the environment - and familiarity is lacking. And the prevalence and strength of the, often reality denying, media has become an overwhelming influence in everyday life for millions of Americans.

Individual and societal commitment to truth seeking and truth telling is also a prerequisite for innovation. If attempts at innovation are not dispassionately examined and criticized, there is no way of saying whether or not they are successful - especially since, by its very nature, innovation attacks the conservatively held status quo. With no truth criteria for success, the spirit of innovation founders. Yet, in addition to stretching and distortion of truth in advertising media whose presence is ever growing, we also see growing disdain for truth seeking - and the more specific mores of science - in political and regulatory processes. We see attacks on both the substance and process of science - e.g., governmental denial of the scientific consensus on global climate change, and one-sided stacking of scientific review boards (cf., *Science*, **305**, p.323, 16 July 2004).

This is not to say that the prevailing consensus, at any time, should be immune to attack. It is to say that government is not the appropriate agent for such necessary challenge. An example of what can happen when government attempts to become an agent of challenge is the wishful thinking represented by the nuclear isomer bomb: the attempt to fund the development of new weapons whose physical basis runs counter to consensus scientific reviews and paradigms.

Unfortunately, feeding more money, students, and foreign scholars to the body of American science will not ensure that it continues to stand tall in the world. Its legs continue to lose strength. We scientists can no longer just accept financial support from the society in which we are imbedded without being concerned with, and attempting to influence, the critically important cultural infrastructure upon which our viability, both as scientists and as a society, is absolutely dependent.

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LETTERS

Stewardship The issue not raised in David Hafemeister's survey of stewardship (P&S, July,2004) is, does the cost justify the diplomatic gains? I estimate that stewardship costs about $4 billion/year, plus of course the cost in good minds tied up in simulating warheads that could be tested every few years for ~$100 million. For the difference we could send a manned expedition to Mars in a decade or two! Which is more significant? And of course our abstinence has no effect on the spread of weapons. In the time since we stopped testing, Pakistan and India have tested, and North Korea has developed warheads. Face it: other nations do not much care if we test; after over a thousand tests, it is a finished issue. None of this seems to permeate our decisions.

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BOOK REVIEWS

The Precautionary Principle in the 20th Century–Late Lessons from Early Warnings
Poul Harremoës, David Gee, Malcolm MacGarvin, Andy Stirling, Jane Keys, Brian Wynne, and Sofia Guedes Vaz (Editor), Earthscan Publications, London, 2002, xx + 268 pp., $29.95 US, ISBN 1-85383-893-4.

This book is devoted to case studies of adverse environmental or public-health consequences resulting from 19th and 20th century technological progress. Three of the case studies cover environmental issues (fish stock overexploitationm, Chapter 2; halocarbons' impact on the ozone layer, Chapter 7; and tributyltin's effects on mollusks, Chapter 13). Eight studies examine the unforeseen negative health consequences arising from some industrial innovations (ionizing radiations, Chapter 3; benzene, Chapter 4; asbestos, Chapter 5; synthetic hormones, Chapters 8 and 14; antimicrobials, Chapter 9; and bovine spongiform encephalopathy, Chapter 15). Finally, four studies are devoted to situations where both environmental disturbance and public-health adverse consequences are found (organochlorine compounds, Chapter 12; PCBs, Chapter 6; sulphur dioxide, Chapter 10; and methyl tert-butyl ether or MTBE, Chapter 11).

All of the authors, all associated with the European Environment Agency, were asked to follow a similar structure in presenting their case study, by answering four questions:

- When was the first scientifically-credible early warning of potential harm?
- When and what were the main risk-reduction actions or inactions taken by regulatory authorities and others?
- What were the resulting costs and benefits of the actions or inactions, including their distribution between groups and across time?
- What lessons can be drawn that may help future decision-making?

Also, each chapter includes a table summarising the historical development of the problem studied.

None of the case studies illustrates a positive application of the precautionary principle. In all instances, action was undertaken too late to avert adverse consequences. Hence, it could be said that the book justifies the legitimacy of the precautionary principle by illustrating how its absence in the scientific assessment of technological innovations has led to undesirable results. While the majority of the case studies compare the approaches undertaken in different countries, there are no clear instances where application of the precautionary principle by some countries spared them the undesirable consequences suffered by less foreseeing countries. In that sense, the precautionary principle would be strengthened by additional comparative studies.

One interesting observation that comes through in many of the case studies is that a desirable industrial property – stability – becomes quite undesirable when a product finds its way in the environment, or in living beings. Immune to break-up by biological processes, that product permanently affects the biological tissues or ecosystem where it accumulates. Indeed, asbestos and PCBs derived their industrial importance from their stability, and their bad reputation in environmental circles from the very same property.

In the final two chapters, the editors infer some general lessons from the fourteen case studies discussed. These fall into three groups: lessons on the need for scientific thoroughness; lessons on the responsibilities of experts acting as influential stakeholders; and lessons on the need for honest communication with the non-experts.

Concerning scientific thoroughness, the editors highlight the need for experts to recognize the areas where scientific evidence is shallow or assumptions are unrealistic, and to actively advocate the need for better science while avoiding 'paralysis by analysis' (waiting for irrefutable evidence at the price of letting potential problems become actual). The paralysis-by-analysis dilemma is most colorfully stated by Peter Infante (p. 44):

"Studying a subject to death often results in the death of those we are trying to protect." The editors also insist on the need for long-term monitoring, based on the observation that, in all of the case studies, acute manifestations were the exception rather than the rule. One such exception was ionizing radiation exposure.

As policy-makers or advisers to decision-makers, scientists have a special duty to avoid an overly reductionist approach in favor of an integrated approach. This would entail considering local and lay knowledge as well as scientific knowledge, assessing not only the technological innovation under scrutiny but also all of its alternatives, and thinking globally instead institutionally or disciplinarally. This duty also entails the ethical obligation to maintain independence from the various stakeholders, which appears to have been an issue in the handling of bovine spongiform encephalopathy by the government of the United Kingdom.

Finally, as communicators of scientific evidence to the public, the editors emphasise the need for scientific experts to properly explain to the public the limitations of scientific knowledge: the areas where ignorance rules, and the tentative nature of scientific knowledge, in contrast with the myth of certain scientific proof. The editors also highlight that effective public communication requires the scientist to understand the assumptions and values of the various stakeholders.

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Enough: Staying Human in an Engineered Age

Bill McKibben, Henry Holt and Co., New York, 2003, 271 pp., ISBN 0-8050-7519-4 paperback, $14

Many of us are uneasy with the rapid pace of technological advance during our lifetimes, perhaps particularly those of us who are past 50. For some it is the difficulty in programming our VCRs or learning to use our new digital cameras that makes us feel insecure and inadequate. Others are concerned with the sense that our world is limited and that we may be doing things that are irreversible or at least extremely harmful. In this regard the threats of global warming and species extinction come to mind. These threats to our well being and security are in some sense understandable to us and to many suggest clear courses of action.

In our age of increasingly powerful computers, continual miniaturization of machines, and incredible advances in biology, some see new and much more ominous threats that could strike at the core of how we define ourselves and of what we might become. In his book *Enough*, Bill McKibben is concerned about new technologies that he claims could eliminate our species as we presently know it and replace us by biologically programmed organisms or perhaps by superior robotic beings. Most of his book is concerned with genetic engineering, although some space is devoted to the possibility of rapid advances in miniaturization of integrated circuits and memory devices leading to the science fiction writer's prediction of intelligent, perhaps even self-aware, robots with abilities far superior to our own. McKibben is also concerned with the potential of nano-technology to provide machines capable of producing almost anything we desire essentially free of any cost in human labor and effort. But by far his greatest concern is with the potential of genetic engineering to alter our genome and create a new species of humans with enhanced intellect, superior athletic ability, more stable or sensitive emotions, and even immortality. The title succinctly sums up the author's premise, namely that we are on the verge of going too far too fast and that now is a critical time to reign in these new technologies before in the name of progress our humanity is engineered out of existence.

Many of us might immediately agree that real dangers lie ahead and that it would be best to slow down or suspend some initiatives to give us time to evaluate their consequences. But I believe that McKibben overstates his case by taking for granted the most optimistic predictions of the potential of these new technologies and giving only limited space to possible inherent limitations on genetic engineering, nano-technology and robotics. Are self-aware super intelligent reproducing machines really possible? Is immortality a real possibility for all or even some of us? Will it ever be possible to fine-tune the human genome to the point that one can precisely order up a child with the exact emotional, intellectual and physical characteristics desired? These questions are not seriously debated in this book.

This book raises serious questions and predicts a troubling future. In addition to assuming the most optimistic predictions of technological achievement. it also assumes specific answers to several important philosophical questions which might be summed up in one enormous question: "What is the meaning of life?" Among McKibben's answers is that we are defined by striving and mortality. Therefore if the future evolves as he predicts and we live forever in a perpetual state of retirement with our every want satisfied, the assumption is that our lives will have lost all meaning. Many happy, healthy retirees might put a more positive spin on this scenario.

Genetic engineering, the dominate issue addressed by this book, offers the promise of the elimination of many hereditary diseases and also significant enhancements and alterations of the genetic structure of a child. McKibben's primary concern is that this will enable parents to essentially program their children through enhancements of specific attributes to be star athletes, world class musicians, brain surgeons, etc. He assumes that the nature versus nurture argument is essentially settled and that we are what our genes determine us to be, that genetically programmed children will grow up without any real choice as to what life they will pursue. These superior beings will not only become a different human species but will also live impoverished lives, not having to strive for success and without any real control as to what they become. If they are genetically altered to be immortal they will lose a defining characteristic of our humanity, namely our mortality.

If McKibben is correct, then we are all preprogrammed at birth**;** we just don't know the exact nature of our defining genetic code. If we realize early on in life that we have the physical attributes to be a star basketball player then we would have no choice but to enter the NBA draft as soon as we graduate from high school. However one could argue that even if one has superior capabilities they must be nurtured and developed; one does not become a Nobel Laureate without hard work and dedication. This book doesn't seriously consider these arguments and doesn't recognize that many people are born with superior capabilities in many areas. Which if any of these abilities are developed often depends on choice and circumstance. Moreover, such extensive genetic modification of our children, even if possible, might not be desirable for many parents. After all, given the choice, wouldn't many parents prefer to raise children that are like them? Many other troubling assumptions are raised by this genetically deterministic view of life.

We should all be aware and concerned about the impact of the rapidly developing technologies discussed in this book. But we need a more balanced and complete exposition of the actual potential of these technologies and their impact. Moreover, if one agrees that many of these new developments should be controlled, this book devotes little space to describing how this might be achieved. In the end how one might realistically control such potentially dangerous yet appealing technologies is a difficult if not impossible task.

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Toward Nuclear Abolition: A History of the world Nuclear Disarmament Movement, Volume 3, 1971-present

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Since the beginning of the nuclear era many organizations have devoted their efforts to curbing the growth of nuclear weapon stockpiles and eventually abolishing them. A question of interest to historians as well as to those who have been involved in the movement is how effective have they been. This is the subject addressed by Lawrence Wittner in this book.

It covers the period from 1971 to the present with its main emphasis on the 1980's. Before that time the major issue of these groups was the banning of nuclear testing. This was a success in that the treaty of 1963 banned atmospheric tests, but it failed in the larger purpose of stopping the nuclear arms race since testing underground continued. The bulk of the book summarizes the activities of more than one hundred organizations and coalitions all over the globe, with more than 100 pages of footnotes. Thus the book is not an easy read, but it serves as a good reference book for anyone interested in one or more of these groups. For the organizations in Western Europe the major issue was the opposition to the deployment of intermediate-range weapons, cruise missiles and the Pershing 2, in these countries. In spite of massive protests involving hundreds of thousands of people, the missiles were deployed starting in 1983. However, Wittner says that the pressure from these groups, as well as the Nuclear Freeze movement in the USA, led Reagan to engage in arms control talks. With the coming to power of Gorbachev in the Soviet Union these led to the INF Treaty signed in December, 1987, which eliminated the intermediate-range weapons in Europe as well as the SS-20's in Russia.

The major issue for the USA was the fight against deployment of the MX-missile with its 10 warheads. Scientists' groups particularly emphasized the destabilizing effect of the MIRV (Multiple Independently-targetable Re-entry Vehicles). In fact there had been a move to ban these in the SALT 1 talks, but it never happened, as discussed by Gerard Smith in his book *Doubletalk* in a chapter titled "the great MIRV mystery". After much debate Congress funded 50 MX missiles. Wittner claims this as a victory for the movement since originally it was proposed to have 200. However, in retrospect the deployment of 50 MIRVed missiles at the time the cold war was ending was absurd. At the present time, following the Bush-Putin Strategic Offensive Reduction Treaty (SORT) between Bush and Putin, the MX is finally being dismantled, although the warheads are being stockpiled instead of being destroyed.

On two other issues there was victory. After billions of dollars spent on the "Star Wars" program or SDI (Strategic Defense Initiative), the program was ended. Also the Comprehensive Test Ban Treaty was negotiated and signed. Both these victories have now been reversed by the Bush administration.

With the end of the Cold War the groups under discussion went into a deep decline. However the great dangers from nuclear weapons have not disappeared. Even after SORT the USA and Russia will each have about 2000 missiles pointing at each other and many more warheads in reserve. As a measure of the dangers, the famous "doomsday clock" of the *Bulletin of Atomic Scientists* was advanced to 7 minutes to midnight.

The book tends to overemphasize the successes and the effectiveness of these movements. However, I think a fair conclusion from this book is that powerful groups working towards the reduction and eventual abolition of nuclear weapons are a necessary, but clearly not a sufficient, condition for progress on this problem. Given the danger that continues even after the Cold War, a possible conclusion is that there is a need for the revitalization of these groups today.

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