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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 (2000 words maximum, technicalities are encouraged), letters (500 words), commentary (1000 words), reviews (1000 words), and brief news articles, are welcome. Send them, in hard copy plus (if possible) a 3.5-inch Mac or PC disk or email, to the editor or (for reviews) to the reviews editor. Editor: Art Hobson, Physics Department, University of Arkansas, Fayetteville, AR 72701, 501-575-5918, fax 501-575-4580, bitnet ahobson@uafsysb. Reviews editor: Kenneth Krane, Department of Physics, Oregon State University, Weniger Hall 301, Corvallis, OR 97331-6507, 503-737-4631, fax 503-737-1683, bitnet Kranek@Physics.Or.State.Edu. Typist: Sandra Johnsen. Layout: Page Perfect of Fayetteville.

LETTERS

Global Warming

"Global warming" (April 1992) is, at least so far, a chimera for everyone who hates free enterprise to warn against. It is not established that temperatures have risen or will rise; these are predictions by computer models of uncertain reliability. We may well expect that increased carbon dioxide will cause increased plant life which will tend to move the global system back to steady-state. Should temperatures begin to rise, increased cloud cover from increased evaporation could reflect enough solar energy to again decrease the effect.

The dirty secret of the extremists who call for drastic changes in lifestyle and oppressive regulation of the economy in response to every half-baked apocalyptic alarm is that they are not nearly as worried about the welfare of real people as they are of the choices those people make. People insist on wanting to live where they should not; they want the personal freedom that comes from driving their own car. It appears from your editorial that finally, the worst sin committed by the common man is that he doesn't want to learn enough physics.

William Dozier
Argonne National Lab

I read your editorial with great interest. I have degrees in mathematics, physics, operations research, and economics, so I am interested in interdisciplinary approaches to problems (1). Your editorial addressed two of the three issues that I had hoped that eventually your quarterly would discuss.

First, the economics of environmental issues suffers greatly from a lack of input from scientists who are familiar with the physics of the issues. Your editorial provided in a very brief space a summary of numerous facts that could be useful to economists working in the area.

Second, perhaps eventually your quarterly will address the fascinating employment problem in physics. [Editor's note: See Al Saperstein's proposal for a new Forum study, in this issue's News section.] Newspapers, magazines, and television have for years bemoaned the pending shortage of scientists and engineers in America, complained about the large numbers of advanced degrees going to foreign nationals, and predicted an imminent decline in American science. I have wondered how to reconcile those stories with periodic letters in *Physics Today* in which physicists at various stages of their careers lament their job prospects. Of course, one can always argue that there will be a shortage of physicists in the long run, but that the recession has created a surplus of physicists in the short run. Perhaps, but this short run problem seems to have lasted at least twenty years.

Finally, economics and physics both seem to have useful applications in the energy area, and it is here that we differ. Attempting to price nonrenewable resources is one of the thorniest problems in natural resource economics. Without cash markets or futures markets, attempts to set prices of goods quickly get bogged down in value judgments. You refer to "pricing gasoline far below its true cost," to the economy being "unresponsive to the true value of its goods and services." How in the world do you know what the "true cost" of gasoline is or the "true value" of goods and services are? You refer to "the scientific age since Copernicus," yet you seem to be adopting the concept of "just price," an idea that goes back to 13th Century scholastics like Thomas Aquinas. Scholasticism argued that there was an ethical value that represented the "just price" (read "true cost") of a good. Needless to say, those arguments weren't science, they were theology. Still I would love to see some discussion in your quarterly of scientific pricing of nonrenewable resources. Perhaps some solutions to the resource pricing problem can be found without physicists rediscovering and reapplying 700 year old ideas of medieval theologians.

1. Charles Dale, "From Kondratieff to chaos: Some perspectives on long-term and short-term business cycles," Futures Research Quarterly, Winter 1990, 71-83.

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James Randi

Let me add one more paragraph to the discussion of James Randi (January and April, 1992). As a consultant to the Committee for the Scientific Investigation of Claims of the Paranormal, I have been watching his valuable work for many years. During this time I have written three books describing what physics has to say about claims of the paranormal (1-3). I have shown in detail that one of the tasks of physics is to decide what things are possible and what things are impossible. That is the function of the symmetry principles governing interactions between objects. The verified laws of nature tell us that perpetual motion machines do not work, that psychic phenomena are fantasies, that astrology is wishful thinking, and so on.

Unfortunately, to those who do not know the meaning of conservation of energy and who do not know the difference between a gravitational and magnetic field, arguments based on scientific principles fall on deaf ears. Therefore people like

James Randi are necessary to give dramatic demonstrations that "psychic phenomena" are merely stage tricks that can be done by anybody who knows the trick. The stage magician provides laboratory demonstration that the laws of natures work.

1. *Discovering the Natural Laws*, Doubleday, New York, 1972; and Dover Publications, New York, 1989.
2. *A Physicist's Guide to Skepticism*, Prometheus Books, Buffalo, 1988.
3. *The Science Gap: Dispelling the Myths and Understanding the Reality of Science*, Prometheus Books, Buffalo, 1992.

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Ethics

On 12 February 1992, a conference was convened in Chicago sponsored by the National Council of Lawyers and Scientists, titled "Responding to allegations of research misconduct in the university: a practicum". An illuminating comment from the floor should be recorded.

The commentator, who was from the National Science Foundation, told of receiving a phone call alleging grave misconduct at a university, and requesting NSF investigation. The commentator told the caller to refer his complaint to internal university channels. The caller's reply was that the result would be a whitewash, and the end of his own career.

That is precisely the experience of many to whom I have spoken, and it is the gist of Alan Westin's 1981 book, *Whistleblowing* (McGraw Hill), about analogous situations in the business world.

Thirty years ago I proposed action on ethical issues in physics to Frederick Seitz, then a past president of the American Physical Society. For 30 years the mountain labored and now has produced a statement on ethics that strikes me as a very sickly mouse. Or perhaps I should call it a piece of poisoned cheese, because naive and idealistic young people may be led to believe the Society intends to take ethics seriously and provide fair and effective enforcement. But before they act on that assumption, they should note quickly that the Society has said nothing about enforcement or about protecting whistleblowers.

I only hope that not too many will be deceived by what is essentially window-dressing, and have their careers ruined. As things now stand, APS is part of the ethical problems of scientists rather than of their solution.

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ARTICLES

Forum Award Lecture: The Role of Physicists in the Nuclear Agreement Between Brazil and Argentina

*Luis Masperi**

Luis Masperi, Fernando de Souza Barros, Alberto Ridner, and Luis Pinguelli Rosa, are winners of the 1992 Forum Award for promoting public understanding of science-and-society issues. Their Award Citation states: "For laying the groundwork for the agreement between Argentina and Brazil to stop their nuclear weapons programs." Luis Masperi is at the Bariloche Atomic Center, Bariloche, Argentina. Fernando de Souza Barros and Luis Pinguelli Rosa are at the Federal University of Rio de Janeiro, Brazil. Alberto Ridner is at the Atomic Energy Commission, Buenos Aires, Argentina. The following article is their lecture at the Forum on Physics and Society's award session at the APS/AAPT meeting, 21 April 1992, in Washington, DC. —editor

Argentine and Brazilian nuclear development and their relationship

The nuclear development of Argentina began in 1950 when the Atomic Energy Commission (CNEA) was created with the explicit aim of pursuing only peaceful applications of nuclear energy. The Asociacíon Física Argentina (AFA) took part in establishing CNEA as a civil institution not depending on the Defense Ministry as was initially suggested.

The original activity of CNEA was devoted to basic research and to building nuclear reactors for research and radio isotope production. In the 1970s power reactors appeared in the country after a public discussion on the more convenient type and the choice, natural-uranium heavy-water reactors, was backed by the scientific community.

During the last military government started in 1976, an ambitious nuclear plan was designed and at the same time the first nuclear companies not completely controlled by CNEA were created. In 1978 a secret project of uranium enrichment by diffusion started, and its success was publicly announced in 1983 a few days before the democratic government took office. This project, declared to be for the fuel of research reactors and to slightly enrich the power reactors, was appreciated as a technological achievement though criticism arose due to its development under a military government whose peaceful intentions could not be completely trusted.

In Brazil, after the first studies begun in the 1950s and the creation of the Commission of Nuclear Energy (CNEN) in 1956, the 1970s saw the purchase of one power reactor and in 1976 a huge nuclear agreement with Federal Germany which was severely criticized by the scientific community. Because of the lack of technological transfer in this agreement, the military government developed a parallel plan controlled by the Navy which achieved ultracentrifuge uranium enrichment within a broad program for building a nuclear submarine. Moreover a deep hole on a Brazilian Air Force base was denounced by the

Sociedade Brasileira de Física (SBF) as having been prepared for an eventual underground nuclear test. Recently the autonomous nuclear plan was put under the formal responsibility of CNEN.

Since 1983 AFA and SBF have held several meetings and made declarations condemning nuclear weapons all around the world and urging the constitutional governments of Argentina and Brazil to reach agreements of cooperation in nuclear affairs and forms of mutual control. SBF succeeded in obtaining the prescription in the Brazilian Constitution of exclusively peaceful nuclear activities with the approval of Congress. A similar constitutional amendment was proposed in Argentina by AFA. The collaboration of the Federation of American Scientists was of great value during all of this period.

Is it not allowed to dream that the next millennium will start without any nuclear danger?

The joint declaration of collaboration on peaceful nuclear applications, between the Argentine and Brazilian Presidents, and the unprecedented visits of President Sarney to the Argentine enrichment plant of Pilcaniyeu and of President Alfonsín to the Brazilian one of Aramar, were steps of mutual understanding. They achieved their final goal with the agreement for the exclusively peaceful use of nuclear energy signed in 1991 by Presidents Menem and Collor de Melo in Guadalajara. By this agreement both countries ban from their territories forever the possibility of building, testing or acquiring any nuclear explosive device including the so-called explosives for peaceful purposes which cannot technically be distinguished from the military ones. Furthermore, a common system of accounting and control of nuclear materials (SCCC) is established, and an Argentine-Brazilian Agency (ABACC) is created with the purpose of making mutual inspections.

With this agreement years of mistrust and, with the exception of nuclear submarines which are allowed, a potential armament race was avoided. Though they are not nuclear weapons, nuclear submarines may unbalance military equilibrium in the region.

The next step, of accepting full scope IAEA safeguards, was taken at the end of 1991 by the presidents of Argentina and Brazil. This step enters into the rather confused area of international treaties. A bilateral agreement could become unstable if the relations between the countries deteriorate. This suggests the need for an international guarantee. On the other hand it is also legitimate to doubt the preservation of industrial secrecy under these asymmetrical inspections even if they are defined as non-intrusive. It is therefore clear that IAEA must act with extreme delicacy so as not to spoil the agreement.

There has been serious and promising work on the regional Tlatelolco Treaty, which both governments anticipate ratifying. At present this treaty has the loophole of allowing peaceful explosives, and the asymmetry that extra-continental powers that possess Latin American territories are not obliged to submit their military bases to international control to assure the absence of nuclear weapons. These deficiencies of the treaty need to be eliminated to make it effective and to allow the participation of all Latin American countries. This would provide an example for the world of regional denuclearization on the basis of justice.

The future of international non-proliferation treaties

The utmost interest should be focused on the Non-Proliferation Treaty (NPT) which has been signed by around 140 countries, but not by Argentina and Brazil, and which will expire in 1995. The NPT has the merit of diminishing the risk of horizontal proliferation, but is a discriminatory treaty that reflected the scenario emerging after World War II and was adapted to the Cold War balance of power.

Now the scenario of the five great-power winners of World War II has faded. The disintegration of the Soviet Union has produced several republics which were not stated in the NPT to have the right to possess nuclear weapons. In a more ordered way, the unification of European foreign policy will tend to share the nuclear responsibilities of the United Kingdom and France with other partners who, as part of the NPT, renounced nuclear weapons. On the other hand, the Cold War is over. With it has disappeared the logic of the balance of terror, which was argued as a justification for the huge nuclear arsenals of the superpowers which menaced humankind.

With the signing of the treaty the nuclear powers should eliminate their strategic weapons —and agree on a comprehensive test ban.

The risks of the future are that Third World countries might be tempted to acquire nuclear weapons to improve their international situation, and that developed countries might use their weapons to maintain their superiority status. One has to realize that history teaches that no countries are more responsible than others regarding the use of force. Almost without exception every country has, under particular circumstances, produced great loss of human life defending what it believes are its rights.

Therefore, being clear that NPT can no longer be applied as it stands, it is urgent to work toward another treaty that will replace it in 1995, and that will consider all countries in a more balanced way and for the benefit of the whole world. This new treaty should have the declared purpose of banishing all nuclear weapons in the year 2000, with an intermediate stage of five years.

With the signing of the treaty the nuclear powers should eliminate their strategic weapons, which are useless in the present international scenario. And they should reduce their tactical weapons to 50% and agree on a comprehensive test ban. On the other hand, the non-nuclear countries should renounce all means of acquiring nuclear weapons, and should accept full-scope IAEA safeguards on all their peaceful nuclear facilities. All countries should agree to respect each other's right to develop and trade any peaceful nuclear technology on an equal footing provided it is put under IAEA safeguards.

By the year 2000 all nuclear weapons should be eliminated from the world and a single comprehensive verification system should be established to assure global security. It is not allowed to dream that the next millennium will start without any nuclear danger?

*partially supported by CONICET

Szilard Award Lecture: Nuclear Arms Control After the Soviet Collapse

Kurt Gottfried

Kurt Gottfried is winner of the 1992 Leo Szilard Award for promoting the use of physics for the benefit of society. He is Professor of Physics and Chair of the Department at Cornell University. His Award Citation states: "For timely and thorough analysis of the SDI program, crisis stability of nuclear forces, and conventional forces in Europe, which have contributed greatly to the understanding of these issues by the government and the public." The following article is his lecture at the Forum on Physics and Society's award session at the APS/AAPT meeting, 21 April 1992, in Washington, DC. —editor

Transformation of the international scene

The transformation of the international scene that we have witnessed in the last three years is so profound that it would take an Alexis de Tocqueville or a Leo Szilard to make a credible forecast of what it implies for our long-term future. Indeed, even a sound understanding of what is already history will only develop over time.

I used to ask political scientists whether the Czar would have been ousted in 1917 if he had thousands of nuclear weapons. No one I encountered had given any serious thought to the question I was alluding to: Great powers have collapsed throughout history, but how would such a change occur if the authorities facing elimination held a huge nuclear arsenal? Various conjectures seemed plausible—that a violent overthrow would not be dared for fear of losing control over the arsenal; that other great powers would intervene to prevent such a loss of control; that the nuclear arsenal was irrelevant; and so forth.

Proliferation has been abetted, by omission or commission, by certain Western governments and, it appears, especially by China. On the whole, the Soviet government acted responsibly.

A full understanding of how the Kremlin's power collapsed is not yet available. Nevertheless, it is obvious that the nuclear arsenal did not save the *ancien regime*. On the other hand, in the events that began with the crumbling of the German Democratic Republic, the potential threat of a nuclear catastrophe did seem to make all the players, whether in the East or the West, more cautious than they might otherwise have been. Furthermore, enough is already clear to permit us to chart in broad outline how nuclear policies should be adapted to the totally new environment.

The events since 1989 have profoundly altered the nuclear threat itself. On the positive side, there are outstanding *concrete* changes: Presidents Bush, Gorbachev, and Yeltsin have agreed to reduce strategic warheads to about 4000 per side, that is, about 2 times smaller than called for by START, and 3 times smaller than the currently-deployed strategic forces. Unilateral moves by President Bush have led to bilateral commitments to decommission virtually all tactical nuclear weapons except those delivered by aircraft. Of at least equal importance, the end of the Cold War has yielded important confidence-building measures, such as a substantial reduction in the readiness of the strategic forces. Most remarkably, there are now discussions at quite a high-level of collaboration in early warning of missile attack.

On the other hand, the breakup of the Soviet Union has produced a new set of risks. Among the successor states to the USSR there may, in addition to Russia, be nuclear-armed powers with conflicting ambitions and interests. The highly effective command and control over nuclear forces that the Communist regime imposed may not survive the breakup of the Soviet Union. And nuclear weapons technology and expertise may "leak out" of the former Soviet Union (FSU).

That the spread of nuclear weapons and sophisticated means for their delivery poses a serious risk is now, at last, recognized. This risk is not new, of course, but probably it has grown as a result of the Soviet collapse. However, we should not allow this concern to hide the fact that the risk of a nuclear apocalypse is certainly smaller than it was for decades. The only plausible fuse for such a conflagration has disappeared: the cheek-by-jowl confrontation between two conventional armies in the heart of Europe whose non-nuclear might—even in peacetime—dwarfed the strength of those that fought World War II, backed by two prodigious strategic arsenals able on the shortest notice to assume a launch-on-warning posture.

The acquisition of nuclear weapons by smaller powers might well lead to terrible calamities by greatly amplifying the carnage inflicted in regional wars. Nevertheless, the collapse of Soviet power makes it difficult to conjure up a credible scenario that would lead from a regional war to the detonation of thousands of thermonuclear warheads. The likelihood that the continental US will be obliterated by a nuclear attack now seems very remote to Americans of all political persuasions, even if some fear a nuclear attack on a few American targets.

I believe, therefore, that the events of recent years have greatly reduced the danger that the Northern hemisphere will be turned into a radioactive rubble heap, though the probability that we will see some use of nuclear weapons may well have increased.

What, then, are the principal nuclear threats that we still face, and what should be done to minimize them?

Threats from the Soviet arsenal

First, there are the threats that emanate from the Soviet arsenal, which is still largely intact. We all hope that the effort to transform the FSU into a collection of productive and healthy states will succeed. However, there is some risk that this effort will fail and instead give birth to one or more dangerous regimes. If such a regime should find itself in possession a sizable nuclear arsenal, it is likely that it would try to exploit it for political or possibly even military advantage. For such a regime, this nuclear arsenal would be the only card it would have that the West would perceive as a credible threat. Hence it is in our interest to have the Soviet nuclear arsenal reduced as deeply and quickly as possible. Furthermore, this reduction must be seen as fair in Russian eyes. Otherwise the democratic forces in the FSU would be compromised, much as the harsh terms of the Versailles peace settlement undermined democracy in the Weimar Republic.

This last requirement means that the slashing of the arsenals must be enshrined in arms control agreements freely entered into by the successor states to the USSR. Of course, the cuts themselves can be carried out by an interlocking sequence of unilateral acts agreed to informally, as has become the practice since last September. But if these reductions are to be robust, in the sense that they would be likely to survive even if relations with the West become acrimonious, they should be in treaty form. While treaties are not ironclad guarantees, they pose a much higher political hurdle than do unwritten agreements. The breach of a treaty gives clear warning that serious trouble is to be expected, and thereby can deter such a breach.

—And from proliferation

Second, there are the threats from proliferation. Iraq has taught us some important lessons:

- What we complacently call a developing country can mount a strong and sophisticated clandestine effort to acquire nuclear weapons if it is ruled by a determined dictatorship with deep pockets.
- US *and* Israeli intelligence, and thousands of overflights during the Gulf War, failed to discover the extent of the Iraqi effort.
- The measures for enforcing the Non-Proliferation Treaty (NPT) administered by the International Atomic Energy Agency in Vienna cannot uncover even a major clandestine nuclear weapons program.
- Furthermore, this failure is not the fault of the IAEA, but of the international community which has not given the IAEA the power and means for doing a proper job.

Proliferation has been abetted, by omission or commission, by certain Western governments and, it appears, especially by China. On the whole, the Soviet government acted responsibly.

Now, however, the enormous Soviet nuclear weapons complex represents a massive potential source of expertise, fissile materials, weapons components and perhaps even weapons. So much has been written about this that I will only mention a few points.

According to Bush Administration testimony before Congress (1), the governments of the FSU have established an impressive program for gathering and disabling tactical nuclear weapons. The NATO and Russian governments are cooperating in a well-financed effort to contain nuclear weapons expertise in the FSU, though the speed and efficacy with which this program is being established remains unclear (2). The most often expressed worry is that Soviet expertise could help technically unsophisticated or poorer states to cross the nuclear threshold. But such expertise could also allow states that already have or will later have fission weapons to acquire a thermonuclear capability *without testing*, something that, I am told by Hans Bethe, could not be done on one's own; and it could also teach such states how to make more compact and therefore more deliverable weapons.

A proposal

The residual threat posed by the Soviet arsenal, and by the enhanced prospect of proliferation, require the creation and implementation of policies designed to cope with these threats. Such policies will not see the light of day unless the US government leads the way.

A proposal that sets out in some detail the various components of such a post-cold war arms control regime has been constructed by myself and Ambassador Jonathan Dean, a senior retired Foreign Service officer, under the auspices of the Union of Concerned Scientists (3). I shall summarize the principal points. But before I lose myself in the trees, I want to point out the nature of the forest. First, it should not be forgotten that if the West agrees to symmetry in nuclear weapons between itself and the Soviet republics the West will not be abandoning its economic and political superiority, and the US will also continue to be the world's only global conventional military power. Second, the US-Soviet arms control regime should be structured in a manner that gives maximum support to the nonproliferation regime. How this could be done is illustrated by the package of proposals that I will now summarize:

Reductions in superpower arsenals. The first and in some ways most important step would be an agreement setting the goal of reducing the US and Soviet republic arsenals to a level of about 1000 strategic *and* tactical warheads for each side, with the eliminated warheads and their delivery systems *destroyed.* These "small" arsenals would be structured to be secure against preemptive attack, and would thereby eliminate the pressure to rely on launch-under-attack or launch-on-warning, which is the most dangerous characteristic of the situation we have lived with in recent decades. This cut would go well beyond what has been agreed to thus far: not only are the numbers smaller by a factor of four or so, but it would be far more irreversible than START and the Bush-Yeltsin agreement which do not require destruction. While the ultimate objective would be agreed to at the outset and quite unambiguous, implementation of this reduction would have to be in stages in accordance with a negotiated schedule and would, furthermore, be contingent on participation by the other nuclear powers once the lower levels are reached.

In adopting no first use, the declared nuclear powers would make a significant contribution to the outlawing of nuclear weapons, the basic NPT objective.

No new strategic weapons. Agreements to constrain the introduction of new strategic weapons (i.e., on missile flight tests, production, etc.)

Fissile material production ban. Agreement to formally halt all production of fissile material for weapons, with all nuclear production facilities on both sides, including military facilities, under bilateral and IAEA monitoring.

Comprehensive test ban. Agreement *now* to the Comprehensive Test Ban Treaty (CTBT), which would come into force in five years or so following a phased reduction in the number and yield of underground tests (4).

The objective of the last two policies is primarily to reinforce the nonproliferation effort. The NPT, as it stands, legitimizes a severe double standard that undermines the objectives of the treaty: The declared nuclear powers can do essentially whatever they please in building their nuclear forces, whereas the non-nuclear powers are expected to obey stringent and intrusive restrictions on their civilian nuclear activities—not to mention the requirement to abstain from any and all military nuclear efforts.

Limits on other nuclear arsenals. Agreement by the other three declared nuclear powers to limit their arsenals to about 500 each, to accept the same verification measures and restrictions on testing and production as the US and the Soviet republics, and to adoption of the CTBT.

Improved NPT. United action by the five nuclear powers to press for indefinite renewal of the NPT in the 1995 review conference; and a supplementary understanding to the NPT making mandatory IAEA inspection of all nuclear plants and challenge inspections of "unreported" activities.

No first use pledged by all five nuclear powers. Throughout the cold war the threat to use nuclear weapons to defend against a conventional attack was fundamental to NATO policy. However one may have viewed the credibility of this policy, what led to its adoption—Soviet conventional advantage in Europe—has disappeared. The adoption of no first use (NFU) would have to be more than a pledge, of course, and be made concrete by removing nuclear weapons from essentially all commands (in the case of the US, from such unified commands as the Pacific and Atlantic Commands), and by refraining from exercising nuclear forces in conventional maneuvers. In adopting NFU, the declared nuclear powers would make a significant contribution to the outlawing of nuclear weapons, the basic NPT objective.

Enforcement

Once the foregoing steps have been taken, the declared nuclear powers as the five permanent members of the UN Security Council would be in a position to make the Council the principal enforcer of the NPT, and to back this with a commitment that the Council would undertake joint punitive action against NPT violators, including governments that fail to compel their private companies to comply with the provisions of the strengthened NPT regime or with the strictures of a strengthened regime for the control of technologies related to other weapons of mass destruction and sophisticated means for their delivery.

Finally, when all these (and other) pieces are in place, the Security Council would request all states that were not signatories to the NPT to become NPT signatories by relinquishing their nuclear program, or to declare themselves as nuclear powers and subject themselves to the restrictions imposed on the other nuclear powers, or to become members of a regional nuclear arms control regime such as that in South America. It would be understood that the Security Council would take measures permitted by the UN Charter against states that refused to accept any of these options and showed a determination to remain totally outside the global nuclear arms control regime.

Obviously, so grandiose a scheme is open to a host of nitpicking and serious criticisms. In particular, it is contingent on the adoption of rational policies by a multitude of governments not only in relatively safe environments but also in dangerous areas such as the Middle East. Nevertheless, I would argue that it describes with reasonable accuracy the problems that must be addressed, points in the direction that should be taken, shows that the task before us is prodigious, and highlights that for the first time in forty years we have the opportunity to put the nuclear genie, largely, if not wholly, back into the bottle. This opportunity must be seized now by adopting an entirely new set of policies. No government other than that of the United States is in a position to lead the way. We, as physicist-citizens, must make every effort to have our government assume that responsibility.

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The Role of Science in a Changing World

James D. Watkins

It's a pleasure to be here this evening, to talk with you about "the role of science in a changing world." Dr. Richter has asked me to focus particularly on how the dramatic changes now occurring worldwide are likely to affect support for basic science and long-range research.

The challenge to the US in the 21st century

Certainly, science has changed our world in the 20th century beyond anything ever imagined in the entire march of human history. The discipline of physics has made a major contribution to shaping our world in the last 50 years. The long period of the Cold War, coupled with the existence of nuclear weapons, has ordered national policies and shaped careers and personal decisions of millions of individuals in countless ways. The Cold War both determined and gave meaning to many of the policies and institutional arrangements that we've long taken for granted—including support for both basic science and applied research.

But now, with the end of the Cold War, many of these verities—these institutional arrangements and agreed ways of doing business—are being called into question. The "old world order," built around defense R&D as a major source and rationale for funding of science and engineering in the US, is now changing.

It seems clear that the challenge to the US in the 21st century will be primarily *economic*, rather than military. We must remain competitive in a dynamic global economy. Meeting this

James Watkins is US Secretary of Energy and an Admiral of the US Navy (Retired). This article is based on a talk given at a joint session of the APS and the AAPT, at the APS/AAPT meeting in Washington DC, 21 April 1992.

challenge demands new thinking and new approaches from all of us—in government, business, industry, and academia. Just as we worked together successfully to meet the *military* national security challenge that confronted the US and our allies over the past half-century, we now must forge new partnerships to meet the competitive *economic* national security challenge over the *next* half-century.

Basic research will continue to be the underpinning of partnerships in the 21st century. Many of the promising recent breakthroughs in science—high temperature superconductivity, the polymerase chain reaction for amplifying DNA sequences, buckeyballs—have come from individual investigators following their scientific instincts, and not from large, centrally-directed scientific enterprises.

Big science, small science

While both "big science" and "small science" have roles in the next century, I believe we must take special concern to protect and nurture small science across many disciplines, including physics. This special treatment is needed because large projects tend to develop political constituencies very easily, and can quickly overwhelm the system.

As you know, about six months ago we had to address a situation at DOE where so many big physics projects (BPX, main injector, B-factory, RHIC, CEBAF, APS, SSC) were either in progress or being added to the budget that they threatened to destabilize our base of support for small science, as well as skew the disciplinary balance of our program too much towards certain subfields of physics. Under the leadership of will Happer, and with the assistance of a distinguished panel of scientists chaired by Charles Townes, we made some very difficult decisions that I believe were necessary to preserve the overall integrity of our programs.

This year, we are soliciting advice on priorities for both vertical slices of our program (high energy physics) and horizontal slices (across all disciplines) that will enable us to put forward the most scientifically exciting and fiscally responsible program possible. Small science will continue to be a prominent feature of our program. For fiscal year 1993 I directed that DOE's budget submission for basic research include a $50 million increase dedicated to small science at universities. This is a trend we expect to continue in future years.

The long-range basic research we undertake today will certainly be the wellspring for tomorrow's technologies. The research enterprise is a *continuum*, in which the federal government is a key player. We see it as a matter of national priority—and as a duty to the taxpayer—to transfer the results of federally-funded research to American industry, which can apply the in the marketplace.

New ideas in technology transfer

The idea of "technology transfer" is certainly not new, but the emphasis now being placed on it is The Department of Energy (DOE) has made technology transfer an important focus of all its programs and laboratories. We have some very clear direction and support from Congress in this effort. The Federal Technology Transfer Act of 1986 authorized DOE's four government-owned, government-operated laboratories to enter into formal cooperative research and development agreements (CRADAS) with industry. This precedent-setting authority was expanded under the National Competitiveness Technology Transfer Act of 1989 to cover all of DOE's government-owned, contractor-operated laboratories, including the defense-related labs.

We are very pleased with the positive response of both contractors and industry to our new technology transfer policy. Today, approximately 100 CRADAS have been signed between DOE's laboratories and facilities and outside parties, including private companies, universities, standards organizations, and state agencies. An even larger number are now in negotiation.

If the Federal government is not abandoning or diminishing its commitment to basic science and long-range research *per se*, what indeed is the issue as government-industry-academic relationships are altered to meet a changing world where national economic competitiveness is vital? I believe at least a partial answer lies in the expanded role that government laboratories can play as "facilitators" or "connecting points" in achieving the kind of continuum that is needed—a continuum running from basic science to applied research and technology transfer to the private sector.

In what could prove to be the most important step toward achieving a practical electric car, the three automakers and the electric industry entered into a joint research agreement with DOE called the "US Advanced Battery Consortium."

Let me give you an example of what I mean: Last October, in what could prove to be the single most important step toward achieving a practical electric car, the big three automakers, General Motors, Ford, and Chrysler, and the electric utility industry entered into a joint research agreement with DOE called the "US Advanced Battery Consortium." The goal is to speed development of advanced battery technology and bring electric vehicles into the commercial marketplace before the end of the current decade. Consortium members are now sharing equally with DOE in the projected $260 million cost of this planned four-year research effort.

What is truly different in this consortium is that DOE is not simply funding research and "hoping for the best." Instead, we are participating as *partners* in the research effort, contributing not only funding but also the technical excellence of our laboratories *and our knowledge of the expertise resident in universities and other research institutions*. Thus, government/industry partnerships like the Advanced Battery Consortium may actually encourage a greater flow of industry as well as federal dollars to university-based researchers who can contribute to solving problems.

The Federal government—with its continuing interest and support for basic science, *together* with its new responsibilities for technology transfer and emerging partnership with American industry and academia—can facilitate the flow of information from scientists and researchers to developers and users of technology. This, of course, is a key to creating wealth and to developing a better educated society. And make no mistake, an American economy fully competitive with other nations is the only way to ensure more resources for basic and long-range research.

Indeed, I believe basic researchers can benefit in many ways from links to the world of applied science and industrial development. Where choices are possible for conducting basic research within several different systems, there may be real value in choosing research designs with the greatest potential for practical application—with no compromise to science.

Science education

In the long run, there is no investment in science more important than the investment in *future scientists*—in science education. DOE's science, mathematics, and engineering education programs are an essential component of the overall federal commitment to ensuring America's international economic and technological competitiveness.

DOE's ten multiprogram national laboratories and 30 specialized labs provide an educational resource that is unique in the Federal government, and perhaps in the world. Not surprisingly, many of our educational programs are laboratory-based. For example, the national labs have developed formal alliances with historically Black college and universities and minority institutions to provide comprehensive, long-term technical assistance to upgrade research and teaching capabilities. They also reinforce the ability of these schools to attract and retain minority students in scientific and technical fields. Activities include faculty research opportunities at DOE facilities, student research opportunities, visiting scientists programs, seminars, assistance in new course development, and loans of scientific equipment.

Overall, DOE's fiscal year 1993 budget request for support of science/math/engineering education is $114 million. This represents a 170% increase over FY 1990! These funds, which finance precollege, undergraduate and graduate-level programs, are administered primarily through the Office of Environmental Restoration and Waste Management and the Office of Energy Research. The first of these two Offices supports development of new undergraduate-level education programs and curricula in the environmental sciences. Scholarships are available for undergraduate students committed to careers in environmental remediation; and funding is available for regional partnerships involving university consortia, DOE laboratories and private industry to develop joint research and continuing education initiatives in environmental sciences. The Office of Energy Research maintains two distinct education programs, directed primarily toward pre-college and undergraduate students. One, designated the Laboratory Cooperative Science Centers, is a lab-based pre-college program offering research and training opportunities for both faculty and high school/grade school students at DOE laboratories. The so-called University Programs, which are college or university-based, are designed to encourage more young people—particularly under-represented women and minorities—to pursue energy-related scientific and technical careers.

> *Every projection I have seen for future electricity demand points toward a need to bring back the nuclear option —with a new generation of inherently safe reactors.*

Perhaps the most visible of DOE's education initiatives is the National Science Bowl. This event is a tournament-style academic competition between teams of outstanding high school students who qualified for the national finals by winning regional science bowls around the country. This year, approximately 12,000 students and teachers from 2000 high schools participated in the regional eliminations. The 30 winning teams will meet in Washington DC for the national finals, beginning this weekend and continuing through the beginning of national science and technology week, next Monday. Participation is an important event in the lives of the students. Winners receive national acclaim, as well as recognition in their communities. We consider the National Science Bowl a major incentive to students throughout the country to excel in science and math—and to elect science studies when they enter college.

Earlier this month, I announced establishment of DOE's distinguished postdoctoral program, in which fellowships—including a $52,000 stipend—are awarded to outstanding individuals who have already earned doctorates in areas of physical, engineering or computational sciences critical to DOE. Up to ten fellowships will be awarded each year, and these may be extended for up to two additional years. Selection of awards is made by panels of experts within the respective disciplines, including DOE laboratory scientists.

Nuclear power

I do *not* believe that the end of the Cold War means that society will automatically have any less need for nuclear physicists. The phrase 'atoms for peace,' which was coined with such confidence in the fifties—and frankly, the object of such disappointment in the eighties—*can* be given new meaning in the nineties, and well into the 21st century. Every projection I have seen for future electricity demand points toward a need to bring back the nuclear option—with a new generation of inherently safe reactors. The national energy strategy recognizes this reality, and lays out a comprehensive program of regularity reform and research, designed to fulfill the promise of nuclear power. And if, as many assume, the future of mankind lies in the exploration of space, we will surely need a vital science of nuclear physics to make this possible.

Conclusion

The history of the relationship between the Federal government and universities or private research institutions on the one hand, and American business and industry on the other, has been amazingly productive.

The development of high-speed computers, modern aircraft and satellite communications are among the many technologies that have received major support from NASA and the Departments of Energy and Defense. American agriculture is the most productive in the world—due largely to plant and animal sciences pioneered by the Department of Agriculture and the nation's land grant colleges. American medicine has benefited enormously from research sponsored by the National Institutes of Health and other federal health agencies—research often performed in universities and non-government laboratories. And surely, the quality of American life today owes a great deal to the science of physics and the important technologies it has generated—nuclear medicine, laser technology, fiber optics, industrial imaging devices—many of which have their basis in federally-sponsored research.

These are just a few examples of the enormous progress science has given us—progress science and technology *together* must continue to give us.

REVIEWS

The Energy Sourcebook: A Guide to Technology, Resources, and Policy, edited by Ruth Howes and Anthony Fainberg

American Institute of Physics, New York, 1991, 546 pages, hardcover $75, $60 to AIP or APS members, paperback $35, $28 to members.

The Energy Sourcebook represents the conclusions of the Forum's recent energy study. Written for general audiences as well as for physicists, it is a comprehensive and technically accurate compendium of information on the sources and uses of energy and the energy options available to the US. It is intended to heighten public awareness and interest in current energy policy and research before the US reaches an energy crisis forced on it by political, economic, or environmental upheaval elsewhere in the world. It reviews each major energy source, comparing advantages and shortcomings. It should be of interest to environmentalists, scientists, teachers, and students.

The book's table of contents:

Global Warming: Physics and Facts, edited by Barbara Goss Levi, David Hafemeister, and Richard Scribner

AIP Conference Proceedings 247, American Institute of Physics, New York, 1992, 512 pages, hardcover $95, AIP or APS members $76.

This book resulted from a 1991 conference organized by the Forum at Georgetown University in Washington, DC, in 1991. It is written for physicists, scientists, and policy makers in a diverse range of fields from government to industry to academia. It provides the in-depth technical background needed to fully understand the scientific issues surrounding this high-profile topic.

The book's table of contents:

Recent Journal Publications

The dropping of the atomic bomb on Hiroshima was a watershed in world history and constitutes, for many physicists, the quintessential science-and-society issue. Evidence bearing upon the American decision-making process continues to surface. A recent exchange in *International Security* (Barton Bernstein's article in Spring, 1991, and correspondence from Gar Alperovitz, Robert Messer, and Bernstein in Winter 1991/92) presents some of the latest thinking, and provides much reference material.

A thorough account of Iraq's progress toward a nuclear weapon can be found in the report by David Albright and Mark Hibbs in the January/February 1992 issue of the *Bulletin of the Atomic Scientists* .

Performance of the Patriot defensive missile in the Gulf War has become a matter of controversy after initial journalistic exuberance—particularly as its success has been used to generate support for SDI. Theodore Postol, who has contributed much in the way of independent analysis of ABM systems, presents a painstaking study of Patriot in *International Security*, Winter, 1991/92. Using publicly available data, he concludes that Patriot did not "significantly reduce ground damage from Scud attacks against Israeli cities." In rebuttal to Postol's and other criticism, a detailed report entitled "Patriot ATBM Experience in the Gulf War" has been privately circulated by Robert Stein, Manager of Raytheon Company's Advanced Air Defense Programs. This report, I believe, will be published.

Not convinced that global warming is complicated? A paper by Gifford Miller and Anne deVernal in *Nature* , 16 January 1992, page 244, shows that in the geological record of the last 130,000 years, ice sheets *increased* under conditions that would be expected with global warming. And there is an extensive study of biomass as a means of offsetting CO_2 production, by D. Hall, H. Mynick and R. Williams, in *Science and Global Security*, volume 2, numbers 2-3.

The October 1991 *Scientific American* features a frightening story on the current state of oil-spill cleanup technology, including reports from Prince William Sound and the Persian Gulf. The Exxon Valdez spill "tore off the veil of preparedness." Elements of the cleanup may have caused more ecological harm than good.

Michael Sobel
Brooklyn College

NEWS

The frequent exclamation marks found in the news section are meant as calls to action, reminders that the Forum hopes its members will actively involve themselves in physics-and-societal matters!

Appeal for Donations to Support our Colleagues in the Former Soviet Union!

To the members and friends of the American Physical Society:

I am writing you to request that you consider making a donation on the order of $50 or more to a special fund to assist physicists in the republics of the former Soviet Union (FSU).

Many APS members have conveyed to me their sense of urgency about the need for a prompt response to the crisis that confronts our colleagues in Russia, Ukraine, Belarus, the Baltics, and several other republics of the FSU. To that end, I have asked the chair of the APS Committee on International Scientific Affairs (CISA), William A. Blanpied (of NSF), to convene an ad-hoc task force to advise the APS Executive Board and Council on actions we can take to maintain the best of what has been a world-class physics enterprise. Other members of the task force are Anthony Fainberg (Stanford), Herman Feshbach (MIT), George Gamota (the Mitre Corporation), and Kurt Gottfried and Yuri Orlov (Cornell). Irving Lerch at APS Headquarters is providing staff backing.

As one of its first actions, the task force recommends creating an emergency fund gathered from donations from concerned APS members. I endorse that recommendation and ask that you contribute $50 or more (or less if that amount is not feasible). The task force intends to draw on that fund to provide journals to FSU institutions. It is also considering a small grants program to assist physicists of proven ability to pursue their research. To implement these ideas, the task force hopes to establish counterpart committees in the western FSU republics, particularly Russia, Ukraine, Belarus, and the Baltic States.

If you are willing to contribute, please send your checks (payable to the American Physical Society) to: American Physical Society, ATTN: Task force on the crisis in the FSU, 335 East 45th Street, New York, NY 10017.

The task force is also investigating the feasibility of direct shipments of small pieces of donated equipment and "obsolete" computers to specific FSU physicists. Members interested in pursuing this option should indicate in their response what equipment they would consider giving. Gifts of cash and equipment are deductible to the extent allowable by federal law. The APS Council expects to identify members with experience in the FSU who are willing to volunteer to assist in developing assistance programs. If you are among those who qualify, please signify your willingness to provide the task force with the benefit of your experience along with your donation.

Looking beyond the next few months, I have asked the task force, minus its chair, to prepare a draft proposal to the National Science Foundation (as well as other Federal agencies such as the Department of Energy and private foundations) to support a substantial program through which the APS can provide assistance to FSU physicists remaining at their home institutions, in addition to brokering some exchange of physicists between US and FSU institutions. The foci of such a program should be on outstanding established physicists and younger physicists of proven ability, with the objective of preserving the next generation of physicists. I will keep you abreast of these developments through APS News and by other means.

American physicists have long been proud of belonging to an international community in both word and deed; of coming to the aid of their colleagues abroad in their hour of need. This is such an hour for our colleagues in the republics of the FSU, many of whom have played courageous and even seminal roles in the democratic transition that has evoked such universal admiration. By acting now, you can help one of the world's most creative physics communities to survive.

Sincerely yours,
Ernest Henley
President, American Physical Society

1992 Forum and Szilard Award Winners

Luis Masperi, Fernando de Souza Barros, Alberto Ridner, and Luis Pinguelli Rosa, are winners of the 1992 Forum Award for promoting public understanding of science-and-society issues. Their Award Citation states: "For laying the groundwork for the agreement between Argentina and Brazil to stop their nuclear weapons programs." Luis Masperi is at the Bariloche Atomic Center, Bariloche, Argentina. Fernando de Souza Barros and Luis Pinguelli Rosa are at the Federal University of Rio de

Janeiro, Brazil. Alberto Ridner is at the Atomic Energy Commission, Buenos Aires, Argentina.

Kurt Gottfried of Cornell University is winner of the 1992 Leo Szilard Award for promoting the use of physics for the benefit of society. His Award Citation states: "For timely and thorough analysis of the SDI program, crisis stability of nuclear forces, and conventional forces in Europe, which have contributed greatly to the understanding of these issues by the government and the public."

The two award lectures were given at the Forum's award session at the APS/AAPT meeting, 21 April 1992, in Washington, DC. They are reprinted in this issue.

Past Forum Chair Barbara Levi composed two of her inimitable limericks for the occasion. For Fernando de Souza Barros, Luis Masperi, Luis Pinguelli Rosa, Alberto Ridner, on receiving the Forum Award:

Argentina and also Brazil
Both bowed to their physicists' will.
They vowed to rebuke
Their plans for a nuke
And turned a test site into fill!

For Kurt Gottfried, on receiving the Szilard Award:

Now SDI never made sense
(Not to mention its soaring expense!)
With Kurt in the lead
Have we now Gott-fried
Of *such* foolish plans for defense?

Newly-Elected APS Fellows, Sponsored by the Forum on Physics and Society

Arnold B. Arons: For pioneering work in the teaching of physics and leadership in the education of future teachers of physics

Benjamin S. Cooper: For his many contributions to national American energy policy, from his position on the staff of the Senate Committee on Energy and Natural Resources.

Alexander DeVolpi: For innovation, research and leadership in applying physics for arms control verification and for contributions to public and government enlightenment on societal consequences of modern technology.

Robert Ehrlich: For application of physics to aspects of the nuclear arms race and contributions to public education in physics.

Barbara Goss Levi: For her objective analyses and expositions of the physics behind many nuclear weapons issues, and for her lucid explanations of current research for the readers of *Physics Today*.

Robert H. Romer: For his innovative energy-based physics textbook and other writings on the energy problem, and for his editorial work for the entire physics community.

Dietrich Schoeer: For his interpretation of science to the public, and for his efforts to get physicists and students to think analytically and professionally about the social implications of their technical knowledge.

Forum Election Results and New Officers

The Forum's recent elections produced 1125 voters, 25% of the Forum's membership. The newly-elected officers are Marc Ross as Chair-Elect, Anthony Nero as Vice Chair, Caroline Herzenberg as Secretary-Treasurer, and two new Executive Committee members: Lisbeth Gronlund and Jill Wittels. The revised Forum Bylaws were approved by a vote of 1051 to 13. The complete list of Forum Officers for 1992-93 is as follows:

- Chair: Anthony Fainberg
- Chair-Elect: Marc Ross
- Vice Chair: Anthony Nero
- Secretary-Treasurer: Caroline Herzenberg
- Past Chair: Ruth Howes
- Forum Councillor: Barbara Levi
- Executive Committee: Lawrence Badash, Lisbeth Gronlund, Cindy Schwarz, Julia Thompson, Jill Wittels

Suggestion for a Forum Study: Jobs and Careers in Physics!

The National Science Foundation has issued reports indicating that there is, at present and for the foreseeable future, a major shortage of scientists (including science educators) in the United States. The clear implication is that the prosperity of the US depends upon the scientific-educational community significantly increasing its output. Presumably there will be good jobs and long productive careers waiting for all the young physicists we will turn out. And yet the letter columns of *Physics Today* and other journals and newspapers are full of complaints from good young physicists, decrying the evident absence of physics careers for them. There seems to be a feeling of having been seduced into embarking upon physics careers and then being abandoned at the point where permanent careers are expected to start. Furthermore, the validity of the NSF projections has been publicly questioned. What are we to believe? More importantly, what is American society and its young, just contemplating their future careers, to believe?

As physicists, we have always been eager to be surrounded by apprentices, and believed that our society would support growing numbers of physicists. Do these beliefs contradict the realities facing our younger colleagues?

The American Institute of Physics has a long history of compiling believable professional educational, employment, and career statistics. As physicists, we have a fundamental commitment to the truth, whether or not it is favorable to our aspirations. As the Forum for Physics and Society, we have an obligation to the well-being of our colleagues—young and old, present and future—and of our general society. We have access to the resources to carry out and disseminate a first rate study of the possibilities and requirements for future careers in American (and world?) physics. Such a study would not only satisfy our obligations, it may demonstrate to all the importance of the Forum and hence increase our membership among present and future young physicists.

If you are interested in joining such a study, see the next article for further information!

Alvin M. Saperstein
Department of Physics
Wayne State University
Detroit, MI 48202

Suggestions and Volunteers Needed for Forum Studies!

The Forum on Physics and Society is looking for ideas and volunteers for one or more new Forum studies!

The Forum has carried out and published three past studies, of civil defense, land-based strategic missiles, and energy. These resulted in the publication of three books, *Civil Defense: A Choice of Disasters*, Dowling/Harrell, AIP 1987, *The Future of Land-based Strategic Missiles*, Levi/Sakitt/Hobson, AIP 1989, and *The Energy Sourcebook*, Howes/Fainberg, AIP 1991. In each case, one or more study organizers suggested a topic to the Forum, and the Forum's Executive Committee discussed and approved the topic. The Forum and the study group leader then sought out study group members who were willing to donate some of their time over a one or two year period to meet roughly twice with the study group, to gather information on their particular topic within the overall study, and to write the portion of the study dealing with their topic. The Forum is able to provide travel funds for the study group meetings. Before publication, the entire study is reviewed and discussed by the entire study group, and is then reviewed by outside experts.

Study group members need not be experts on the chosen topic, although of course experts are welcome also. As broadly-educated physicists, study group members who do not begin as experts can educate themselves and *become* expert. As a member of the past study group on strategic missiles, I can testify that this is a stimulating process! Thus, Forum studies are learning experiences for the study group members, for the Forum, and for the physicists and others within and outside the sciences who might later learn from the published study.

The Forum is looking for a few good people, and a few good ideas, for future studies! All physicists are welcome!

Alvin Saperstein suggests one study topic, currently being considered by the Forum Executive Committee, in the preceding article. If you are interested in possibly joining a study group on jobs and careers in physics, contact him! Conventional weaponry is another study topic currently under consideration. If you are interested in possibly joing a study group on conventional weaponry, contact the Forum's Past Chair: Ruth Howes, Department of Physics & Astronomy, Ball State University, Muncie, IN 47306, phone 317-285-8868, fax 317-285-1624, bitnet OORHHOWES@BSUVAX1! If you have other suggestions for a study topic, or if you want to be kept informed of other possible study groups, contact the Forum Chair: Tony Fainberg, 320 Galvez Street, Stanford, CA 94305, phone 415-725-6488, fax 415-723-0089! And published letters to *Physics and Society* , suggesting and discussing possible study topics, are always welcome!

Join the Forum! Receive *Physics and Society*!

Physics and Society, the quarterly of the Forum on Physics and Society, a division of the American Physical Society, is distributed free to Forum members and libraries. Nonmembers may receive it by writing to the editor; voluntary contributions of $10 per year are most welcome, payable to the APS/Forum. We hope that libraries will archive *Physics and Society* . Forum members should request that their libraries do this!

APS members can join the Forum and receive *Physics and Society* by mailing the following information to the editor or to the APS office!

I am an APS member who wishes to join the Forum:

NAME (print) ______________________________

ADDRESS ______________________________

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COMMENT

Remarks From the Outgoing Chair

The 1991-92 year proved a turbulent one for the Forum on Physics and Society (FPS) in a number of ways. First, the internal changes in APS structure have had a direct impact on the FPS. FPS Bylaws have been reworked under the able leadership of former Secretary-Treasurer Heinz Barschall to add a Vice Chair to the list of FPS officers, to redefine the duties of the officers, and to bring our procedures into line with the new APS constitution.

The new constitution allows formation of a "Forum": a unit of general interest to physicists in a variety of specialties. A Forum has a single representative on the APS Council no matter how large its membership may be, and is not required to charge extra dues for membership although it is financially supported by the APS. In addition to the FPS, Forums on Education, and on the History of Physics, have been or are in the process of being established. And there has been discussion of establishing a Forum on International Physicists. It is clear that the FPS will no longer have a unique "Forum" status within the APS. We face a major challenge in developing working relations with the other new Forums while retaining FPS's unique character.

A second major challenge to the FPS this year has come from the rapid changes that have occurred in global politics. While the entire structure of conventional arms control has changed, new issues have arisen in dealing with Soviet physicists and renewed concern for the global environment. FPS must define its role in working within this new format for global problems. While we have discussed these issues in sessions at APS meetings, in *Physics and Society*, and in the FPS Executive Committee, we will have to increase efforts to understand how best to have a constructive impact in this new global society.

In addition to considering these new challenges, Forum has had an excellent year. Our invited sessions at both the March and April general meetings were well-attended and stimulated much discussion. We can all be proud of the new Fellows we have named and the recipients of the Forum and Szilard Awards. *Physics and Society* has continued to publish interesting and varied articles and letters. The Forum on Physics and Society has done its job very well.

All the Forum officers, the Executive Committee, and the committee chairs have worked hard and well for the organization. In particular, we thank our retiring Secretary-Treasurer Heinz Barschall for four years of service. He not only managed to keep our books in balance and minutes flowing, but also rewrote the Bylaws and managed to secure us royalties from Forum studies. We will miss his sound council and financial good sense.

Finally, we have elected an excellent slate of officers for next year. Tony Fainberg, who has served as Chair-Elect this year and has been responsible for Forum programs, will serve as Chair. Marc Ross has been elected Chair-Elect; Tony Nero, Vice Chair; Caroline Herzenberg, Secretary-Treasurer; and Lisbeth Gronlund and Jill Wittels are new members of the Executive Committee. I wish them all the best as they face the challenges of the upcoming year.

Ruth H. Howes

Mathematics and International Security: An Essay for Math Awareness Week

Readers will be familiar with the applicability of mathematics to completely predictable systems: to design of automobiles and television sets, the construction of guns and intercontinental missiles. Anybody who has ever taken a science or engineering course is aware of the pervasiveness of mathematics in these subjects. The mathematics predicts the consequences of design concepts and changes: If this part is attached in this way here, then that part will function thusly there. This "if—then" process is deterministic: Every step necessarily follows from the preceding step. Knowing the position and velocity of a missile (or a planet) now, and the laws of physics governing the environment through which it is to travel, mathematical ballistics successfully predicts where it will be at any later time.

Also commonly understood is the mathematics of completely non-deterministic situations, such as gambling and human mortality tables, those in which chance is dominant. The result of a coin toss tells you nothing about the results of the next toss.

New and interesting is the mathematics of chaos, the "prediction of unpredictability," and its application to scientific matters and to national policy questions.

It is interesting to note that there are deterministic mathematical systems which cannot predict the future. For example, though the motion of every drop of fluid is uniquely determined by its previous motion and the motions of all surrounding drops, the total motion of a turbulent liquid cannot be predicted. The nature of turbulence is such that no matter how carefully you look at a particular small section of a gurgling brook, you cannot say precisely what will happen to the flow at the next moment, there or elsewhere. Such motions are said to be "chaotic." The nature of chaos is that a very small disturbance, for instance a mote of dust falling on the surface of the brook, may produce a very large change in the consequent motions of the water. Since we cannot say whether or not such small disturbances will occur, and if so where, we cannot predict the future motion.

However, though mathematics cannot predict the motion, it can predict the circumstances under which it will be unpredictable! Mathematically, we can determine the conditions under which the motion will be extremely sensitive to extremely small disturbances. This can still be very useful. Though the detailed motion of turbulent air over a wing cannot be predicted, knowing what wing shapes and flight patterns will result in turbulence is very important in governing the safe design, construction, and operation of aircraft. Knowing whether or not turbulent flows and forces will be present is important in designing hydraulic structures such as bridge and pier footings, deep water oil wells, etc. Similarly, knowledge of the conditions governing the onset of turbulence is necessary for understanding heat flow, whether in the interior of stars or in keeping your home comfortably warm or cool. The mathematics of chaos is also now used to understand the difficulties of predicting the weather (whether the sensitivity of atmospheric motions is such that the fluttering of a butterfly's wings in Beijing will influence the weather in Detroit!) or the behavior of the stock market.

If we can predict the breakdown of predictability in fluid flows or the weather, maybe we can do the same for the interactions between nations.

How can the mathematical ability to predict unpredictability be of use in international society studies?

The outbreak of war—the prime breakdown of international security—has often been attributed (by historians, military analysts, and political analysts) to a collapse of predictability and the consequent loss of control over events. If you don't know what is going to happen, you don't know what to do to get what you want, or avoid what you don't want. Thus, the transition from the usual hostile competitiveness between nations to an all-out shooting war can be likened to the transition from smooth laminar flow to chaotic turbulent flow in a moving body of water. Certainly, the phenomenon of large consequences arising from a small disturbance is similar—the shooting of a minor archduke in Serbia set off World War I, a major disturbance resulting in over 20 million deaths.

If we can predict the breakdown of predictability in fluid flows or the weather, maybe we can do the same for the interactions between nations. If we had a mathematical model of the relations between states in the international system, and if that model predicted unpredictability (chaos) in the system under certain conditions, then that model would be predicting the outbreak of war under those conditions. If we wish to avoid war, then we must change the conditions, change our courses of action, before we get too close to the chaotic state.

How can we create a manageable deterministic model of interacting nations when each nation is a complexly interacting collection of many complexly functioning people? Mathematical physics has a long successful history of using simple mathematical laws to describe gases made up of very many complicated molecules. The very equations which describe both the well-behaved laminar flow and the chaotic turbulent flow of fluids, or the succession of blue sky and stormy weather days, are the result of appropriate averaging over countless complex molecules and their behaviors. It is natural to assume that similar averaged equations can be written down for the international system.

For example, a mathematical model of the Strategic Defense Initiative (SDI) has been created which describes the feedback between competing nations as they procure Intercontinental Ballistic Missiles (ICBMs), SDI weapons to shoot down ICBMs, and weapons to destroy the SDI weapons. If you buy so many ICBMs, I'll buy so many SDIs; if I buy so many SDIs, you'll buy so many anti-SDIs, etc. The questions asked of the model are whether the international system will respond to the introduction of SDI by changing from a strategy of deterrence by mutually assured destruction (MAD) to a purely defensive system, and whether the response will be stable (peaceful) or chaotic. If the mathematical solutions indicate a stable decrease in the number of offensive ICBMs, the answer to both questions is "yes"; if the mathematics predicts unpredictability, it won't matter which weapons—defensive or offensive—are predicted to dominate since an undesired outbreak of war is likely. As expected, the answers obtained from the model depend upon the conditions assumed.

Similar models have been developed to address the questions: Is a multi-polar world of many powerful nations more or less stable than a bi-polar world dominated by the US and USSR? Is a world of democratic states more or less stable than one of autocratic states? Is a world in which nations form and abandon alliances to maintain a "balance of power" more or less secure than one in which nations seek their security independently? The answer to each question is obtained by mathematically examining the models to determine the conditions under which they predict unpredictability. These questions are being actively explored by scholars applying the newest methods in the old subject of mathematics—"queen of the sciences"—to the new problems in mankind's enduring concern with international war. The results reconfirm the old adage about the major consequences of minor events: "For want of a nail a shoe was lost; for want of a shoe a horse was lost; for want of a horse a battle was lost." —And so a kingdom was lost, and for want of a kingdom a world was lost, all for the want of a nail!

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Guest Editorial: Growth in Perspective

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Compressing the 3.5 billion years of life on Earth into the time-scale of a single year, with the earliest microorganisms making their debut on the first day of January, humans didn't appear on the scene until just a few minutes before midnight on the last day of December. The beginnings of agriculture can be traced to about 11:58:30 pm; the earliest civilizations to 11:59 pm; Christ was born at about 20 seconds before midnight; the medical and hygienic breakthroughs which marked the onset of exponential population growth came at about 3 seconds before midnight; and nuclear weapons were developed less than a half-second before midnight.

To put the 60 seconds of human civilization in perspective, it took primitive microorganisms from 1 January through 18 April to learn how to survive the deadly rays of the sun; until then they hid out in the mud. It took only a day (about a million years) after the "invention" of photosynthesis for the atmosphere to be flooded with its poisonous waste product, oxygen, but the buildup occurred so quickly that most of the life on the planet was exterminated before the trick of respiration was learned (which essentially enabled photosynthesis-practicing ecosystems to breathe the waste product of their own metabolism).

Although the exponential growth of the human population began only three seconds ago, already we outweigh every species of animal on the planet—. In the past half-second we have undone much of what life has done in a year—

Dinosaurs made their debut on the sixth of December, and bowed out on the twenty-first. Their parting roughly coincided with the colorful explosion of the angiosperms (flowering plants), which, with their highly concentrated stores of energy, made it possible for large warm-blooded creatures to survive and then to flourish. It took all of the eight-and-a-half months since the cyanobacteria (precursors of modern chloroplasts) invented photosynthesis in mid-April to cleanse the atmosphere of carbon dioxide, which made up somewhere between 5 and 30 percent of the early atmosphere, but constitutes less than one-half of one-tenth of one percent today. (The process of photosynthesis uses the sun's rays to break apart water molecules into their hydrogen and oxygen constituents, and to combine the hydrogen with carbon dioxide sequestered from the atmosphere to make carbohydrates. Most of the carbon is then recycled, but about one-tenth of one percent makes its way into "long-term storage"—calcium carbonates and fossil fuels—where it is kept out of circulation for millions of years. The amount of organic carbon stashed away in the earth has grown quite large over the eons, which is fortunate for us, because if it were still in the atmosphere, global temperatures would be well over 100°F hotter than they are today.)

Thus, throughout the long year of preparation for the spectacular 60-second show of human civilization, the biota has been slowly and assiduously pushing the Earth away from the hot, lifeless equilibrium that can be interpolated from its chemical make-up and its position between Venus and Mars. The anthropocentric notion that humans are unique in their ability to shape and manipulate their environment is wrong: nothing could be more "unnatural" (read chemically unstable) than a planet covered with carbon fuels, bathed in a volatile atmosphere of oxygen. Yet for 2.5 billion years the concentration of oxygen in the atmosphere has been held at precisely 21% (the biota's "mute consensus"—if it were even 2 or 3 percent higher, the earth's vegetation would virtually burst into flame) by the enormous pump of photosynthesis. And the oxygen level is only one of many variables that must be maintained within narrow ranges for the whole complex system to work.

Like all systems, the earth "runs" on the entropy difference between its input energy (short-wave radiation from the sun) and its output energy (long-wave radiation to space). As life has evolved it has developed more and more elaborate ways to harvest, concentrate, store, and use the energy available in this narrow margin. The development of progressively more concentrated fuels has enabled progressively higher life-forms to emerge. The radiant energy from the sun is far too diffuse to directly "power" higher life forms such as animals, which depend on primary producers (plants) to collect and concentrate it for them, and to supply the oxygen with which it can be metabolized, through the mechanisms of photosynthesis. Prior to about 21 December in the year of life, large animals had to be cold-blooded and therefore slow and stupid, because the highly concentrated energy sources needed to fuel faster metabolisms didn't yet exist. Large, active, intelligent warm-blooded creatures such as humans only became possible with the advent of the angiosperms and their abundant seeds and fruits.

The exuberant, bountiful Garden of Eden that greeted our earliest ancestors makes today's Earth seem sterile and barren in comparison. Less than two minutes ago, the rolling grasslands of the American west were "teeming with animal life," according to the *Time Atlas of World History*—"giant bison with a six-foot horn spread, towering, beaver-like creatures called casteroides, camels, ground sloths, stag-moose, two types of musk-oxen, several varieties of large, often lion-sized cats, mastodons, and three mammoths: woolly, Columbian, and Imperial. Within a thousand years (ten seconds) of man's large-scale arrival most of them were gone—including all the horses, which had to be reintroduced from 16th-century Europe."

Although the exponential growth of the human population began only three seconds ago (when we finally succeeded in short-circuiting the "demostat" of disease), already we outweigh every species of animal on the planet, and appropriate some 40% of the products of terrestrial photosynthesis (the other 5-30 million animal species get the leftovers). In the past half-second we have undone much of what life has done in a year, shredding complex ecosystems, upsetting the delicate chemistry of the atmosphere, flooding vast areas and desertifying others, poisoning the water, salinizing the soil, and exterminating species at a rate unseen since the end of the Dinosaur Age. Extrapolating from current trends, humankind would exterminate more forms of life and sterilize more of the biosphere in the next half-second (50 years) than it has in all of previous history; within 3 seconds the waste heat from human activities would be adding more thermal power to the Earth's atmosphere than the sun; within 5 seconds there would be only one lungful of breathable air per person in the entire atmosphere; and within 50 seconds human flesh would outweigh everything else in the known universe. And if we happened to discover another fresh, unspoiled Earth tomorrow, it would take us only half a second (50 years) to fill it up and wear it out like this one.

The great danger for humanity lies in the way it has temporarily pushed back the natural limits to growth. Like a misguided businessman who sells off his production machinery and calls the proceeds income, we are fueling our economic growth through the liquidation of natural capital: fossil fuels, underground aquifers, soil, forests, etc. Anybody who has fiddled with lawnmowers as a child realizes that overriding the governor or spraying ether in the carburetor makes the motor go faster—but only until it burns out. It isn't true that when the carrying capacity is lost it *never* comes back—but it is true that it takes millions of years, which is longer than we can afford to wait.

The Second Law of Thermodynamics says that entropy increases with every process; in other words, you always undo more than you do. Over the course of the past 3.5 billion years, life has patiently siphoned off "syntropy" (Hans-Peter Dürr's word for information, entropy's opposite) from the sun, to transform the earth from a sterile, harsh, and barren place into what Lewis Thomas described as "the only exuberant thing in this part of the cosmos. —It has the organized, self-contained look of a live creature, full of information, marvelously skilled in handling the sun."

It is precisely that "fullness of information" —the biota's uncanny ability to regulate the climate, the composition of the atmosphere, the concentration of organic matter, etc.—that makes the planet fit for human habitation. If there is one thing that sets apart these past 3 seconds of the year of life, it is the unprecedented rate at which information has been lost. An appropriate caution for the future, if it is to be a future that we would freely choose, might be: If we wish to understand what we are doing, we must first learn to understand what we are undoing.

Joe Harvey