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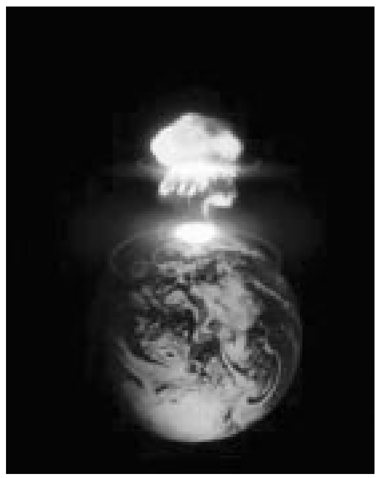
Nuclear Terror: Ambling Toward Apocalypse

By Steven Weinberg



Editor's Note: The following article was delivered as a talk at the 1868th Stated Meeting of the American Academy of Arts and Sciences, held on March 12, 2003, at the House of the Academy in Cambridge, Massachusetts.

It is always an honor and a pleasure to speak to this Academy, but it is a special honor for me to give a talk dedicated to two great men: Herman Feshbach and Victor Weisskopf. I knew them as senior figures at the Massachusetts Institute of Technology: Viki recruited me to the Physics Department, which he chaired, and Herman was director of the Center for Theoretical Physics, where I worked. Of course, long before

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21st-Century Physics: Grand Challenges

By C. Kumar N. Patel and Izzat Jarudi

The course of twentieth-century history was deeply shaped by advances in physics that enabled everything from the nuclear to computer revolutions. The advent of nuclear weapons, for example, revolutionized international politics after 1945 as the foundation for the new doctrine of mutual assured destruction. Half a century later, the advent of al Qaeda combined with the existence of weapons of

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About FAS

The Federation of American Scientists (FAS), founded October 31, 1945 as the Federation of Atomic Scientists by Manhattan Project scientists, works to ensure that advances in science are used to build a secure, rewarding, environmentally sustainable future for all people by conducting research and advocacy on science public policy issues. Current weapons nonproliferation issues range from nuclear disarmament to biological and chemical weapons control to monitoring conventional arms sales and space policy. FAS also promotes learning technologies and limits on government secrecy. FAS is a tax-exempt, tax-deductible 501(c)3 organization.

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I knew them, they had made their reputations as theoretical physicists. Among other things, both had made major contributions to nuclear physics, which in the 1940s became an important factor in world history. Herman's Ph.D. thesis was on tritium, an isotope that later became an essential ingredient in hydrogen bombs. Viki was one of those at Los Alamos who designed the first atomic bombs, and he felt the heat of the first nuclear explosion at Alamogordo from ten miles away.

The experience of participating in the development of nuclear weapons gave a generation of physicists a sense not of guilt but of responsibility—of what Viki called "an obligation to inform the public about the awesome consequences of a nuclear war . . . our nightmarish vision of an actual nuclear conflict, based on our particular understanding of the power of the weapon we had made." To carry out this aim, Viki and others created the Federation of Atomic Scientists. Later, in 1969, Viki and Herman and I joined thirty-eight other faculty at MIT in forming the Union of Concerned Scientists, of which Herman was the first chairman. In the 1970s Viki worked, through the Academy, at organizing conferences on arms control. During Herman's first term as president of the Academy, the Committee on International Security Studies (CISS) was established. These organizations have played an essential role in providing the public with independent scientific judgments about national nuclear policy and other matters.

I wish that I could say that with the end of the cold war, these efforts are no longer needed. Unfortunately, the reverse is true. Since September 11, 2001, we have been painfully aware that there are people in the world who hate America so much that they will give their lives to hurt us. If terrorists succeeded in exploding a nuclear weapon in one of our cities, it would kill so many people and do so much damage that it would make September 11 look like an ordinary working day. Given a hundred pounds or so of highly enriched uranium, it would not be difficult to make a nuclear weapon and put it in an American city, on a truck or plane, or in one of the seventeen million containers that freighters bring into North American harbors every year. Last fall I participated in the Hart-Rudman Independent Task Force on Homeland Security Imperatives, convened by the Council on Foreign Relations. Our task force concluded that "a year after September 11, 2001, America remains dangerously unprepared to prevent and respond to a catastrophic attack on US soil." For instance, we noted, the American Association of Port Authorities estimates that the cost of adequate physical security at our commercial seaports is about $2 billion, yet only $92.3 million in federal grants had been authorized and approved.

Whatever we do to guard our cities, some vulnerabilities will always remain. We also have to guard against nuclear terrorism by working with other countries to control fissionable materials. Russia now holds about 150 tons of plutonium and 850 tons of highly enriched uranium. Since 1991 the United States has been committed to the Nunn-Lugar Cooperative Threat Reduction Program, which among

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other things aims to improve Russian control over these materials to keep them out of the hands of terrorists and other states, and to make them unusable for weapons. Our rate of spending on this program, however, is only about a third of what it should be. The planned upgrade of security has been completed for only about 40 percent of Russian nuclear storage sites, and less than a seventh of Russia's stockpile of highly enriched uranium has been made unusable for weapons. Last year President Bush proposed to cut spending on this program by 5 percent; this year he has asked for only about 10 percent in additional funds. We are not even adequately protecting our own nuclear weapons facilities. Energy Secretary Spencer Abraham has said that his department "is unable to meet the next round of security mission requirements" and has asked for $379.7 million to rectify that situation, but the White House has approved just $26.4 million. There are no technical obstacles here—only a shortage of funds.

One program did receive a flood of new funding after September 11: ballistic missile defense. Pressures for this project had already been revived when Korea fired a three-stage rocket on August 31, 1998, even though that rocket could not have carried a nuclear weapon. More for protection from Republicans than for protection from Korean missiles, President Clinton began tentative steps toward a new antimissile system. During the summer of 2001, Senators Joseph Biden and Carl Levin planned hearings of the Senate committees on foreign affairs and armed services, which might have led to a termination or suspension of Clinton's program. After September 11, those hearings were canceled, and opposition to missile defense collapsed. On December 13, 2001, President Bush announced that the United States would abrogate the treaty that since 1972 had banned the deployment of missile defense by the United States or Russia. This past December he announced the decision to deploy a limited missile defense by October 2004. There is $9 billion in the 2004 budget for missile defense—a figure that will surely increase as the program moves from testing and development to deployment. I have heard estimates that the total cost of the missile defense program through 2014 will reach a trillion dollars.

"Defense Secretary Donald Rumsfeld has upheld the deployment of an ineffective missile defense system by saying that it is better than nothing, but in fact it is worse than nothing."

The irony in the contrast between support for missile defense and for other programs is painful, because attack by ballistic missiles is not only just one of many ways that terrorists could use nuclear weapons against us; it is the least likely way. Terrorists may be willing to commit suicide, but the leaders of the states that harbor them never are. Why should anyone attack us with ballistic missiles, which always reveal their source, rather than in any of the many ways that do not?

Well, I can think of one reason. A rogue state that is in the process of being put out of business by the United States and that has nuclear-armed ballistic missiles might, in extremis, launch them at us. But if that would deter us from adventures in regime change, how would it help if we had an antimissile system of uncertain capability? According to the 2004 budget, the administration plans to deploy an antimissile system that has had no realistic operational tests and does not have the high-frequency radar that had previously been thought necessary. Even if we can build a system and tune it up so that it doesn't keep failing tests, we will never know what sort of decoys or other countermeasures it might encounter. And even if we could protect ourselves, depending on the scope of the missile defense program we might be deterred anyway by the danger of a nuclear attack on our allies. As an audience mostly of academics, I think you will understand what I mean when I call our present missile defense program "pure missile defense"—that is, missile defense undertaken for its own sake, not for any application it might have in defending our country.

The real danger is not that a rogue state will launch nuclear-armed intercontinental ballistic missiles at us, but that it will use nuclear weapons in local conflicts or hand them over to terrorists. There is no easy answer to this. We may have to consider preemptive nonnuclear

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attacks on nuclear facilities, such as the nuclear fuel reprocessing plant in North Korea. On this I disagree with Senators Robert Byrd and Edward Kennedy, who have called on the United States to respect an absolute ban on preventive attacks. There have been times when preventive war would have been necessary and proper—for instance, in March 1935, when Germany announced that it was tearing up the Versailles Treaty and building a military air force.

It would help if the United States could act against nuclear proliferation with clean hands. Under the terms of the 1970 Nuclear Nonproliferation Treaty, we are committed to deemphasize the role of nuclear weapons and work toward their elimination. But there are signs that the Bush administration is trying to revive the idea that nuclear weapons are for use and not just for deterrence. The administration's Nuclear Posture Review, on which I testified in the Senate last fall, has called for the development of Robust Nuclear Earth Penetrators—nuclear weapons for attacking underground facilities (even though such weapons can't be used without creating severe nuclear fallout)—and the new budget contains a small appropriation for this purpose. The chair of the Defense Science Board has called for a study of nuclear-armed antiballistic missile interceptors. White House Chief of Staff Andrew Card has said that the United States would not rule out the use of nuclear weapons in Iraq. President Bush has announced that he will not seek to ratify the Comprehensive Test Ban Treaty. Leaders at the Los Alamos and Sandia weapons laboratories continue to press for a resumption of nuclear weapons testing, and the Bush administration has called for the repeal of the Spratt-Furse amendment, which bans development of low-yield nuclear weapons. For a nation with an overwhelming superiority in conventional arms, the development of nuclear weapons for actual use seems counterproductive to the point of insanity.

Some say that nuclear testing is needed to maintain safety and reliability, but both a committee of the National Academy of Sciences in 2002 and the Council of the American Physical Society in 2003 have concluded that it is possible to maintain confidence in the safety and reliability of the existing nuclear weapons stockpile without actually producing nuclear explosions. Indeed, when we tested nuclear weapons in the past, it was usually to develop new weapons. Personally, I don't think it would be so bad if nuclear weapons on all sides did become somewhat unreliable. We might not then be able to use them for preemptive attacks or bunker busting or missile defense—but what effect would it have on deterrence if there was a possibility that some fraction of our weapons would not achieve the nominal yield?

Meanwhile, nuclear proliferation continues: North Korea today, Iran tomorrow. Even in Brazil, a cabinet minister has called for a nuclear weapons program.

You may not realize it, but so far in this talk I have been looking on the bright side. A nuclear attack by terrorists or rogue states could do terrible damage and kill millions of people, but it would not destroy our country. Only one thing could do that: a mistaken attack on our country by the huge Russian arsenal of nuclear weapons.

It may seem terribly "retro" to mention this danger—akin to suggesting that a modern politician would worry about nineteenth-century issues like bimetallism or free love. Granted, in the present state of international relations, no one thinks that either Russia or the United States would ever plan a first strike against the other. Nevertheless, the strategic nuclear forces of both sides remain frozen in their cold war posture. Each is tasked with the responsibility of being able to respond to an attack by the other side before a single attacking nuclear weapon can reach its own land-based missiles and control centers. This means that the decision to attack must be made in minutes, before any nuclear weapons have actually exploded. It takes only two minutes to launch our own land-based intercontinental ballistic missiles, and less than fifteen minutes to launch our submarine-based missiles. The pressure to decide quickly is more severe for the Russians than it is for us, because they have little left of the invulnerable part of their deterrent (their missile submarines rarely go to sea), and their land-based missiles are vulnerable to a relatively short-range attack by US submarines. In January 1995 the Russian attack decision process was triggered by the launch of a US research rocket from a Norwegian offshore island to study the Northern Lights. The rocket firing was originally mistaken for a launch from an American submarine in the Norwegian Sea, with the separation of multiple stages perhaps giving the impression of an attack by several mis-

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The Afghan Housing Crisis: Can New Technology Make a Difference?

By Henry Kelly

Millions of Afghans facing the coming winter still live in temporary camps or camp in the shells of ruined buildings. Living in temporary housing, with little privacy and unhealthy conditions, many Afghans have not been able to escape the trauma of their protracted wartime environment. Longtime FAS member Art Rosenfeld asked whether the US science community had something useful to offer. The answer seems to be yes. But as might be guessed, finding the right technology to address the housing crisis may be the easiest part of the problem.

The Challenge:

Twenty-six years of almost continuous warfare, coupled with major earthquakes in the past decade, have damaged or destroyed much of the housing stock. Pressure on existing stock is growing rapidly as many of the six million Afghans that fled to Pakistan, Iran and other nations during the war begin to return.[1] A population of 27 million is now struggling to accommodate the more than 1.8 million refugees who were estimated to have returned in 2002 alone.[2] While funding from the US and other nations is woefully inadequate and unpredictable, some progress is being made. Funds typically go to non-governmental organizations (NGOs) with facilities in Afghanistan who struggle to help communities rebuild. In an effort to use local resources and building traditions, as well as to save funds and take advantage of available skills, most of these projects rely on time honored Afghan construction methods, using handmade mud bricks. Flat roofs are supported by wood beams covered by layers of branches, woven mats, and finally up to meter of clay. These structures can be built for less than $1000.

Though inexpensive to build, these traditional homes present major long-term risks. The most obvious problem is that the structures are death traps in earthquakes, and Afghanistan is one of the most active seismic regions of the world. Houses in Afghanistan should be designed to meet roughly the same standards as Los Angeles (4 m/s^2 acceleration), but traditional methods founder at much lower levels. Mud walls are extremely brittle and fail when shaken and the enormous weight of walls and roofs cause disastrous injuries. More than 6000 people died in two earthquakes, four months apart, which shook the Afghanistan /Tajikistan border in 1998, even though they measured only 6.1 and 6.9 on the Richter scale.[3]

Traditional construction has also become more difficult because of the scarcity of wood. Many of the NGOs are forced to import wood from Pakistan and other nations since decades of nonexistent forest management have devastated Afghanistan's local timber supplies. Those not able to import wood are

Demolished House in Kabul

Photo courtesy of www.esamskriti.com

undoubtedly making do with inadequate, and dangerous, roof supports.

Wood shortages also underscore the energy crisis facing the nation. Traditional Afghan homes are heated with wood or charcoal. The difficulty in obtaining traditional fuels has forced many to turn to expensive kerosene or imported coal. Traditional mud homes have enormous thermal mass and can help keep the structures cool in the summer. Kabul has an altitude of 1800 m and nights are cool, but the winters are very cold (the average January temperature is 27ºF) and the mud walls provide little insulating value. These factors force a difficult choice between expensive fuel consumption and uncomfortable temperatures.

Traditional heating and cooking systems also lead to terrible air quality inside the homes. While the mud homes are not airtight, the fires are not vented, leading to enormous buildups of combustion products. Lung and eye problems resulting from these pollutants have devastating effects, particu-

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larly on women who spend a larger fraction of their time indoors and close to the stoves.

The people building new homes in Afghanistan understand the terrible risks they're taking by putting people in unsafe traditional structures, but there appears to be no alternative.

Our Response:

The Federation of American Scientists is spearheading this effort to develop a low cost and energy efficient housing design. We began by talking with everyone we could find who knew something about conditions in Afghanistan and developed a set of performance goals. The result is summarized in Table 1. We sought a design that worked in Afghanistan but since most of the criteria are universal, we hoped to develop a solution that would be widely applicable worldwide – including the US.

We were helped by a number of Afghan engineers and scientists in the US and scholars who have worked in the Central Asia region. Hashem Akbari and Ashok Gadgil from the Lawrence Berkeley Laboratory, Les Norford from MIT, and Kirk Smith from UC Berkeley provided expertise in building technology, energy analysis, and interior air quality. Joe Colaco from the University of Houston (and CBM Engineers), brought expertise in engineering analysis and Roger Rasbach (of Rasbach Design) contributed architectural expertise and extensive knowledge of panel construction.

An attempt to find out how the US assistance program through the State Department and USAID tried to influence the technology of Afghan housing ran in circles. Their main interest is that funds be given to a group that knows how to erect homes in Afghanistan. The otherwise futile pursuit did, however, result in one of those wonderful moments of serendipity, when a State Department official, sotto voce, let us know that one NGO she'd worked with seemed particularly competent. This led to a contact with the humanitarian relief and development organization Shelter for Life International, Inc. (SFL), which has been providing housing in Afghanistan and elsewhere for many years, and their wonderful chief architect Harry van Burik.

We couldn't get serious about design work, of course, without some source of funding. This is the part of any project that no one likes to talk about but lies at the heart of whether anything actually gets done. However important, the project didn't fit into any funder's bailiwick. The California Energy Commission (CEC) was willing to support design work as long as it had clear value for low-cost, seismically resistant, energy efficient housing in California but wanted to cost share with someone. The Department of Energy (DoE), the obvious co-sponsor, has a great staff who completely understood the problem, but their offices have been in a state of constant reorganization and budget tightening. In addition, their mission is energy, not seismic safety or other construction issues. After much negotiation they found funds that could be spent to design energy efficient homes for Native Americans. The combination of DoE and CEC funds allows us at least to start serious analysis of alternative designs and pay for some limited testing of components and integrated building systems.

The Engineering Design

So we were off and running with a semi-impossible set of design specifications and an enthusiastic alliance of a relief & development organization, Afghans, university professors, engineers, architects, Native Americans, and people who represented many dimensions in this space.

Searching for technology concepts in home construction is not an easy task. The industry remains astoundingly isolated from the management and technical innovations that have transformed most other major business sectors. Survivors keep capital investments and core staff as low as possible. Even the largest homebuilders have no research or engineering staff. The construction process is often a game where minimum-bid subcontractors try to minimize costs regardless of the work created for trade that follows them. Lack of precision means that virtually everything – from drywall to cabinet work, must be hand fitted on site.

New house in Nahri
Photo courtesy of Shelter for Life

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Regulatory efforts to increase seismic or wind safety or to increase energy conservation are fiercely resisted and difficult to enforce since the recommended approaches require adding material and labor costs. This is a natural reaction given the industry's lack of capacity for integrating analyses of cost, safety, and efficiency. We, of course, were looking for solutions that were easier and cheaper than conventional methods – techniques where it would be easier, not harder, to meet the performance specifications.

After reviewing a number of concepts, some of them stupendously bad ideas that had been inflicted on other USAID recipients, we are investigating a few versions of a single simple design involving styrene panels coated with a cementitious material that provide both structural strength and a finished coating. These are all variants of Structurally Insulated Panels (SIPs) that are used increasingly in US modular homes. The systems typically create a panel from a sheet of styrene foam insulation sandwiched between two layers of plywood or similar materials. Finish covering is applied to the exterior and interior after the panels are installed. The sandwich has good structural as well as insulating properties, can be assembled much more quickly than conventional homes, and ensures that dimensions are accurate, greatly streamlining all other tasks. These systems eliminate the thermal "short circuits" created, for example, by 2x4 studs that penetrate standard insulated walls. These "short circuits" mean that the actual heat flows through standard walls are 30% higher than would be predicted using the properties of the insulation alone[4] – a figure that is even higher if the insulation is improperly installed.

Performance Specifications

- architecturally attractive to the Afghans (traditional home designs)
- good interior air quality
- seismically stable (design for seismic zone 4)
- comfortable in extreme temperatures with minimal use of external energy sources (e.g. highly energy efficient)
- inexpensive to build (goal is less than $1000 per home)
- inexpensive to maintain (no deterioration from moisture, heavy use)
- secure in high winds
- meets fire-protection standards
- minimal imports
- minimal (preferably no) use of wood
- compatible with sustainable businesses in Afghanistan that can be started with modest capital investment (e.g. <$500K)
- employ people with locally available skills
- minimal or no proprietary technology
- reproducible in other markets (including the US)

We are exploring even simpler systems that simply erect a styrene shell and coat it with a cementitious material that could serve as a final exterior and interior surface. The only materials that would need to be imported to Afghanistan would be styrene pellets and any material that would need to be added to concrete. Styrene pellets are a worldwide commodity made in India and Pakistan. Imported by truck, they can be expanded into sheets in simple facilities (total cost less than $200,000) and increased in volume by a factor of 25.

Preliminary energy analysis by Norford, based on a housing design prepared by SFL and estimated costs, show that an ideal balance between low cost and high energy efficiency can be realized. We will compare at least four separate methods for coating the walls and roofs that have been used in the US and abroad. Colaco will conduct detailed structural simulations that will lead to tests for components of the preferred systems. Norford and Smith will help design simple methods for ensuring interior air quality even when electricity isn't reliable, or even available. We expect that there will be several iterations to optimize both structural and energy designs – something that is almost never done in construction. Typically the energy guys are called to provide heating and cooling after basic design decisions are unalterable. It's likely that structures for Native Americans in California will differ in some details from systems optimized for Afghanistan.

Next steps

One or more small structures will be built in California to validate the construction methods and record the work in a way that can help communicate the methods to Afghans and others. The structures will be tested on a shake table in California that can validate calculations on earthquake performance. We hope that members of the Afghan Urban and Housing Department will participate in the testing. PIR

We plan to begin actual testing late this summer. The diverse back-

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grounds of the team members has put us all on a steep learning curve that, if nothing else, gives us new respect for disciplines we knew little about. So, is it possible to develop a revolutionary construction method that could be cheaper, safer, and more efficient in markets worldwide even in the face of a US deadlock over energy policy? We're giving it our best shot. Watch this space.

1 CIA World Fact Book.

2 Estimates provided are thought to be conservative. See World Refugee Survey 2003, U.S. Committee for - 1s.org/news/press_releases/2003/wrs03_PRscasia 1.cfm

3 http://neic.usgs.gov/neis/eqlists/ eqsmajr.html: On February 4, 1998, an earthquake measuring 6.1 on the Richter scale left 2,323 dead and 818 injured, killed 6,725 livestock, and destroyed 8,094 houses. A second earthquake on May 30, 1998, measuring 6.9, left 4,000 dead and many thousands injured and homeless.

4 w.ornl.gov/roofs+walls/articles/wallratings/index.html

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siles. The Russian response process was stopped only a few minutes short of their ten-minute deadline for a final decision. (Similar episodes occurred in the Soviet Union in 1983 and in the United States in 1979 and 1980.) The pressure on the Russians for quick decisions will become greater as the United States deploys and improves its antimissile system, which could be thought to have some capability against a ragged Russian second strike. Defense Secretary Donald Rumsfeld has upheld the deployment of an ineffective missile defense system by saying that it is better than nothing, but in fact it is worse than nothing. Major General Pavel Zolotarev, past deputy chief of staff of the Russian Defense Council, has said that US missile defense plans make it harder for Russian nuclear planners to consider deep cuts in their arsenal coupled with de-alerting. Can we really assume that Russian judgments about whether they are under attack will always be made correctly, especially if relations between the United States and Russia sour in the future?

Several steps have been taken to ameliorate this danger, all sharing the common feature of being ineffective. In May 1994 Presidents Clinton and Yeltsin agreed that the United States and Russia would stop targeting each other's territory. This is a bad joke; the targeting can be restored in seconds. In 1998 the presidents of the United States and Russia agreed to establish a center in Moscow for the exchange of data on rocket launches. Plans for this center were completed, but it was never brought into operation. In March 2003 the Senate ratified the Strategic Offensive Reductions Treaty, which had been signed last year by Presidents Bush and Putin. It requires a reduction in the number of strategically deployed nuclear weapons on both sides, but the treaty will reduce the numbers only to about 2,000 weapons on each side by 2012, and the delivery vehicles and thousands of weapons taken out of service will not need to be destroyed, only separated.

We need to reduce the number of nuclear weapons on both sides to hundreds, not thousands; to count all weapons, not just those that are strategically deployed; and to take these weapons off hair-trigger alert. Nothing is more important. In any one year, the danger of nuclear attack by mistake is small, and aside from the warnings issued by a few hardy souls (such as Bruce Blair, the director of the Center for Defense Information, and former senator Sam Nunn), it receives little attention. No president of either party has given this danger a high priority. But it is always with us, and in the end it may destroy us.

Author's note:

Steven Weinberg was educated at Cornell, Copenhagen, and Princeton, and taught at Columbia, Berkeley, M.I.T., and Harvard. In 1982 he moved to The University of Texas at Austin and founded its Theory Group. At Texas he holds the Josey Regental Chair of Science and is a member of the Physics and Astronomy Departments. His research has spanned a broad range of topics in quantum field theory, elementary particle physics, and cosmology, and has been honored with numerous awards, including the Nobel Prize in Physics and the National Medal of Science. He also holds honorary doctoral degrees from thirteen universities. He is a member of the American Academy of Arts and Sciences, the National Academy of Science, the Royal Society of London, and the American Philosophical Society. Currently he serves as a member of the Board of Editors of Daedalus, a member of the Board of Directors of the Federation of American Scientists, a Senior Advisor to the JASON group of defense consultants, a National Sponsor of the Committee of Concerned Scientists, and a member of the Council on Foreign Relations Independent Task Force on Homeland Security Imperatives. In addition to the treatises Gravitation and Cosmology and (in three volumes) The Quantum Theory of Fields, he has written several books for general readers, including the prize-winning The First Three Minutes (now translated into 22 foreign languages), The Discovery of Subatomic Particles, Dreams of a Final Theory, and, most recently, Facing Up — Science and its Cultural Adversaries. He is a regular contributor to The New York Review of Books.

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mass destruction like nuclear weapons have again revolutionized international politics as the basis for the new Bush Doctrine of preemptive war.

At the beginning of a new century, the field of physics continues to have the potential to transform the rest of science and society. Our work can lead to tremendous gains in terms of scientific progress and societal welfare if we effectively confront a number of grand challenges that lie before the physics community in the coming decades.

Of course, the claim that there is a well-defined set of challenges for future research is more difficult to defend today than it would have been fifty years ago. The field of contemporary physics is more complex and fuzzy than it used to be. Each physicist has his own definition(s) of his profession. Moreover, the field itself has branched out into a myriad of subfields with interdisciplinary links to formerly distinct sciences like biology. There are few science and engineering departments at universities today that do not include physicists on their payroll. Despite all these difficulties in bounding the question, however, I believe the following nine grand challenges for 21st-century physics should capture the essence of future research.

Grand Challenge #1: Quantum Science and Technologies

In the coming decades, research at the quantum level will continue to benefit from the manipulation of single atoms and molecules through devices like optical traps. The necessary technological developments for that manipulation will allow physicists to treat atoms as "bits" of information for the purposes of quantum computing.

On the other hand, quantum technologies will probably also lead to the observation of novel physical phenomena. The Bose-Einstein Condensate was one such phenomenon, which arose from many atoms of ultra-cold gas being in the same quantum mechanical state with a high probability of spatial overlap.

All of this future physics research will hinge on the development of highly sensitive instrumentation, but the measurement and sensor technologies based on working at the quantum level could fuel progress in other areas of science and engineering through applications like quantum-controlled chemistry, quantum cryptography and highly precise clocks.

Grand Challenge #2: Nanosciences

Like quantum science and technologies, the progress of the nanosciences will be constrained by the current state of the art in nanotechnology. In particular, it will depend on the invention of novel ways of making materials and devices at the nano level like the new techniques that can create "black" silicon.

And once again, the advances in technology will have unanticipated and beneficial consequences elsewhere. In medicine and health, nanotechnology might enable doctors to conduct molecular level surgery and implant nanodevices like atomic magnets in lungs. This important advancement would refine current medical diagnostic and treatment techniques. It could also be applied to energy production and environmental remediation, nanoscale electronics, and nanoparticle based fuels for space propulsion.

Grand Challenge #3: Complex systems

Physicists are often derided for the simplifying assumptions in their models of physical systems (e.g. the famous "spherical cow" joke); however, theoretical advances in physics that relax some of those assumptions could be our best hope for improving our understanding of complex systems. On the more practical side of physics research, large-scale computer modeling and the simulation of linear and nonlinear phenomena such as turbulence and chaos could illuminate complexity at a number of levels and in a variety of domains. For physical systems, modeling and simulation could yield important insight into the properties of real materials under extreme conditions and the explosive deaths of stars. For biological systems, they could move us closer to understanding the human body, social systems, and the economy and perhaps even the stock market.

Grand Challenge #4: Applying Physics to Biology and Medicine

Physics underpins biology, which, in turn, underpins medicine; therefore, the potential for applications

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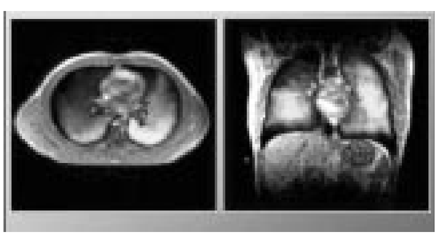
of physics to biology and medicine is enormous. In biology, more physicists should be employed to model molecular processes rigorously such as protein folding. Electrical activity at the cellular level could also be used to understand the functioning of the nervous, circulatory, and respiratory systems. Furthermore, both mechanics and electromagnetism could be integrated in using the electromechanical properties of DNA and enzymes to understand cellular processes.

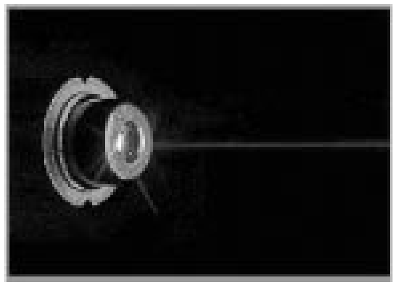
In medicine, physics could inform the design of novel non-invasive diagnostics of the human body such as the use of analysis of breath for understanding biochemistry within the body. Other domains for the application of physics to the medical sciences include the biomechanics of motion and the biophysics of neurons in the brain.



Atomic magnets in lungs

Grand Challenge #5: New Materials

Physicists themselves should also draw on the knowledge of a variety of disciplines, including the natural sciences, to enhance the discovery, development and deployment of new materials. For example, analogies from biological systems could illuminate the self-assembly of complex physical structures and



Blue laser

the role of molecular geometry and motion in restricted dimensions. The synthesis, processing and understanding of complex multicomponent materials such as a blue laser depend on interdisciplinary research among physicists, materials scientists, and engineers.

Grand Challenge #6: Exploring the Universe

One of the grandest challenges of all physics continues to be seeking to understand the origin and destiny of the universe. New generations of tools to explore earlier and earlier moments of the beginning such as the Hubble Telescope could yield the measurements necessary to test the foundations of cosmology. Other engineering marvels could illuminate the nature of the dark matter and energy that constitutes 95% of the mass-energy of the universe or more generally, explore the connections between basic forces of nature and the structure and evolution of the universe. For example, the Laser Interferometer Gravitational-wave Observatory (LIGO) is currently addressing the unsolved theoretical mystery of gravitational waves by trying to directly detect them.

Grand Challenge #7: Unifying the Forces of Nature

Perhaps an even more fundamental challenge than understanding the origin of the universe is integrating the micro and macro levels of nature in a theory of everything that links physics at the tiniest distances to that of the cosmos. Drawing on tools such as increasingly powerful particle colliders, the next generation of experiments should provide a sound footing for the theory to understand the basic constituents of matter. In addition, they could enable us to arrive at a unified description of all the fundamental forces of nature—the strong nuclear force, the electroweak forces, and gravity.

Grand Challenge #8: Physics in Support of Homeland and National Security

A very different kind of challenge arises from the evolving role of our discipline in homeland and national security. Physics promises to support our physical and cyber security by being applied to a variety of areas, including sensors and screening needs, reliable and accurate detection of chemical, biological and explosive agents, and unbreakable quantum cryptographic protocols.

Grand Challenge #9: A Meta-Challenge

The grandest of all challenges for 21st century physics is a meta-challenge above the other research questions: who will be the next

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generation of physicists doing this research? More specifically, will they be Americans or foreigners, men or women, and how do we motivate them? Perhaps more importantly, who will pay for doing physics and how will that affect how we evaluate the relative importance of all these "grand challenges"? Throughout the coming decades, we need to keep reminding ourselves as well as others that the achievements of physics can and should be brought into harmony with the expectations of the society that we ourselves have helped to nurture because the "physical sciences are sciences for creating wealth."

Authors' Note: Dr. Patel, professor of physics, chemistry, and electrical engineering at UCLA. He has made numerous seminal contributions in several fields, including gas lasers, nonlinear optics, molecular spectroscopy, pollution detection and laser surgery. Named one of "85 innovations that changed the way we live" by Forbes Magazine, his invention of the high power carbon dioxide laser at Bell Labs in 1964 ultimately enabled surgeons to perform highly intricate surgery using photons instead of scalpels. He is also a former-president of the American Physical Society and Sigma Xi, the Scientific Research Society. This article was adapted from a talk Dr. Patel gave to the Council of Scientific Society Presidents on May 4th by Izzat Jarudi who is entering his final year of undergraduate study at MIT in the Department of Brain and Cognitive Sciences.

PIR

Making a Lasting Contribution to FAS: Giving Options

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Congress Permits Research on Smaller Nuclear Weapons

By Ivan Oelrich

In 1993, Congress prohibited the research and development of "low-yield" nuclear weapons. The prohibition was included in the Defense Authorization Act and is usually known as the Spratt-Furse Amendment, after its sponsors. The amendment defined "low-yield" as anything at or below five kilotons, which is roughly one third the explosive force of the bomb that destroyed Hiroshima. The Bush Administration specifically asked Congress to repeal this prohibition in the 2004 Defense Authorization.

The Department of Defense's (DoD) draft legislation explained that the ban "undercuts efforts that could strengthen our ability to deter, or respond to, new and emerging threats." What they usually mean by "new threats" are deeply buried or otherwise hardened facilities that might be used to store chemical or biological weapons. The DoD draft also argues that the ban has an overall "chilling effect" on nuclear weapons research and thus inhibits the training of new nuclear weapons designers and generally degrades our ability to respond "rapidly and decisively to changes in the international security environment."

The Administration went to some lengths to argue that repealing Spratt-Furse would only affect R&D, it would not allow production or deployment. In fact, separate statements indicated that the Administration was not even interested in development, only research. For example, on May 20 Secretary Rumsfeld was quoted in USA Today as saying "It is a study. It is nothing more and nothing less." He went on to add "And it is not pursuing. And it is not developing. It is not building. It is not manufacturing. And it's not deploying. And it is not using." The next day, Senator Kennedy, one of the leaders of the effort to preserve the ban, was quoted in the Washington Post as saying, "If we build it, we'll use it." Kennedy and others who wish to keep the ban point out that the Administration's Nuclear Posture Review, only parts of which have been released to the public, tries to portray nuclear weapons as theoretically useable and militarily useful. The New York Times quoted Senator Reed of Rhode Island saying "We have tried for 50-plus years to make these weapons unthinkable and now we're talking about giving them a tactical application. It's a dangerous departure." Indeed, one of the Administration's motivations for building smaller weapons is to overcome current hesitation to use many weapons from the current arsenal precisely because they are too large, some of them having yields of hundreds of kilotons.

> *"The Administration's Nuclear Posture Review... tries to portray nuclear weapons as theroretically useable and militarily useful."*

Efforts to preserve the R&D ban failed in the Senate Armed Services committee, typically on straight party line votes, including an amendment from Senator Levin that would allow research but ban development. Thus, repeal of the ban moved to the Senate floor. Senators Feinstein and Kennedy introduced an amendment on the floor that would have retained the ban and this effort also failed on largely party line votes, three Democrats voting against the amendment and no Republicans voting for it. At this point a tactical retreat seemed the only recourse in the Senate.

While Democratic Senators were trying to preserve the ban on R & D, the House had already inserted language in the authorization bill that would allow research but maintain the ban on development of "low-yield" nuclear weapons. (Technically, the ban was lifted completely, but any development work would require the Administration to come back to Congress for explicit approval and funding.) Senator Reed submitted an amendment to the same effect in the Senate. Before this could come to a vote, Republican Senator Warner submitted his own amendment and used Senate rules to bring it to a vote before the Reed amendment. Senator Warner's amendment was essentially identi-

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cal to the amendment that Senator Levin had presented in committee, which had earlier lost on a party line vote. Although forced to accept a compromise, the Democrats did not want to support legislation that would allow research, so the amendment was passed overwhelmingly, based on Republican votes with a few Democrats crossing. All of the votes against the compromise were Democratic.

The Administration did not accept the compromise, however. The day after the Senate vote, the Office of Management and Budget released its comments on the legislation allowing research but not development. There is no ambiguity, "The Administration appreciates the support for research of low yield nuclear weapons in section 3111. However, maintaining the prohibition on development will hinder the ability of our scientists and engineers to explore technical options to deter national security threats of the 21st century. A complete repeal of section 3136 of the FY 1994 National Defense Authorization Act is needed." This statement supports the "slippery slope" arguments of Feinstein, Kennedy and others and draws into question Rumsfeld's assurances that the administration only wants to conduct studies of the utility of smaller nuclear weapons. The final bill must go through House-Senate conference. With the intent of the two chambers so close, one would normally expect no surprises from the Congressional side, but it is possible that Administration pressure could revive the development question even in this authorization bill.

The Administration's statements on nuclear strategy point toward a robust nuclear posture that includes at least the possibility of using nuclear weapons in disarming first strikes against chemical and biological weapon stockpiles. It is usually posited that these weapons will be stored in very hard or deeply buried bunkers, hence the need for nuclear "bunker busters." Whatever one thinks of the Administration's motives, they cast the issue largely in technical and tactical terms. For example, they want to investigate whether new nuclear weapons may be able to fulfill this and other missions. They repeat that they have not made any decisions; they just want to explore possibilities and options. FAS is ideally suited to engage in a debate framed in this way. If the Administration wants to treat this as a technical exploration, then our technical analysis focuses directly on the core of the debate. For example, Michael Levi's paper, Fire in the Hole, examines the utility of nuclear weapons for attacking buried targets and concludes that only under limited combinations of circumstances would nuclear weapons be better than conventional ones, and the problems of fallout are formidable. As part of the Federation's ongoing review of US nuclear posture, we plan technical analyses of several proposed nuclear missions. We will address such questions as how the targets can be found in the first place, what the effectiveness of nuclear weapons is in destroying chemical and biological weapons compared to conventional alternatives and what the effectiveness is of obvious countermeasures, such as dispersing targets or digging deep targets even deeper.

PIR

Author's Note: Ivan Oelrich is the director of the Strategic Security Program at FAS.

Molecular Manufacturing: Start Planning

by Chris Phoenix

Despite claims to the contrary, molecular nanotechnology manufacturing is coming soon. Because it will be so useful, there will be strong pressure to develop it as soon as possible, and past a certain point it could happen quite rapidly. Macro-scale integrated nanotech manufacturing systems will improve product functionality, product design time and manufacturing speed and cost by orders of magnitude. This advance may profoundly affect economics and geopolitics, creating enormous benefits and risks. It will be difficult to prepare adequately for such a powerful technology. For all these reasons, molecular nanotechnology should be a current topic in high-level policy and planning.

The word "nanotechnology" means several different things. Today's nanotech research is mainly concerned with building small structures that have novel properties. Such research adds steadily to the technological toolbox, leading to improved products and occasionally to new industries. Broadly speaking, such "structural" nanotechnology creates risks comparable to other material science work. The second kind of nanotech is the science-fictional kind, in which nanobots can go anywhere and do anything but generally do not conform to reality. The third kind of nanotech, "molecular" nanotechnology (MNT), is the focus of this article. MNT will combine chemistry and fabrication to produce precise machines and manufacturing systems at the nanometer scale. Much of the basic science work has already been done; what remains is the engineering to create a working device and then integrate many devices into a human-scale "nanofactory". Although most nanotech projects today focus on structural nanotechnology, development of molecular nanotechnology will surely become a priority within a few years. Full MNT capability may not be developed for a decade or longer, but preparation for it should probably start now.

The economic value—and military significance—of a nanofactory will be immense. Even a primitive model will be able to convert CAD files to products in a few hours. Duplicate nanofactories will cost the same as any other nano-built product. The capital cost of manufacturing will be negligible by today's standards, and manufacturing capacity can be doubled in a matter of hours. Nanocomputers will quickly replace semiconductor technologies; whoever controls this technology will be able to produce more computers than the rest of the world combined. The ability to fit a supercomputer (or sophisticated robotics) into every piece of equipment, at no extra manufacturing cost, will enable new kinds of products and weapons. A nanotech-built surgical robot with a full sensor suite could be smaller than a hypodermic needle. Development and deployment of new weapons systems could be far faster and cheaper. Even the initial products of an MNT nanofactory would be worth hundreds of billions of dollars, and the potential for extremely rapid advancement of nanotech fabrication capability means that no economic or political unit can afford to allow a competitor to control the technology.

Much evidence has accumulated to indicate that molecular nanotech manufacturing is possible. A decade ago, Nanosystems studied the required chemistry and engineering in detail; not a single significant error has been found so far. Cells, natural self-replicating machines, make a variety of minerals including magnetite and silica—and they do this under water, using chemical techniques four billion years old. Mechanically guided covalent chemistry has already been accomplished with a scanning probe microscope. The best arguments of intelligent critics regarding the feasibility of nanotech manufacturing have been refuted in detail.[1] There is little doubt that a small self-replicating system can be built. There is strong theoretical support for basing such a system on mechanochemistry. And given the variety of buckytubes, buckyballs, buckyhorns, and other graphitic and diamondoid shapes that have been manufactured or found in nature, it's likely that a self-replicating nanoscale machine based on 3D covalent carbon mechanochemistry will be relatively straightforward to design.

A goal or milestone of MNT is an "assembler": a self-contained mechanical system capable of fabricating duplicates of itself from simple chemicals. Several researchers have investigated the requirements of an assembler, Robert Freitas and Ralph Merkle

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are due to co-publish two books on the topic in 2003 and 2004. A single assembler is not very useful, since it can only make very small products. However, if a nanofactory containing many assemblers can combine the tiny products (nanoblocks) into a single large product, the result would be extremely useful. It has been claimed that this will take years to achieve, blunting the utility of MNT assemblers. However, work by the author demonstrates that a useful nanofactory can be pre-designed,[2] so that building and debugging the design might take only a few months. Once the first assembler is built, a fully functional nanofactory—and the nanofactory's products—may follow in well under a year.

Although design at the atomic level will not be easy, a nanotech product designer will not need to worry about that—just as a software engineer does not think about the transistors in the computer. A small and pre-tested set of nanomachines, built into nanoblocks, can be combined in many ways to make a vast array of products. By designing with nanoblocks instead of atoms, a product designer loses little flexibility, and gains simplicity and reliability. Nanoblocks can be fastened together in a process called "convergent assembly." The joining process uses a single motion, requiring only simple robotics, and the joints retain most of the strength of the base material. A single nanoblock is big enough to contain an assembler, computer or motor, and small enough to be built by a single assembler in a few hours. A nanofactory built of nanoblocks can build and assemble nanoblocks into a huge range of products—including duplicates of itself.

Such a powerful technology introduces many risks.[3] One obvious risk is an unstable arms race. Rapid development of new weapons technologies means less opportunity for surveillance and more uncertainty about the enemy's future capabilities. Weapons could be more powerful and far "smarter"—imagine the combined capability of a million unmanned aerial vehicles with onboard pattern matching and navigation capability. Many factors tempt a preemptive strike if a temporary advantage is gained in an MNT arms race. The likely outcome of a strike would be either global domination requiring Draconian measures including denial of technology, or a series of increasingly destructive high-tech conflicts. Once weapons, or the systems that produce them, are dispersed, preventing guerrilla use of them would require inspection of literally every cubic millimeter, or continuous surveillance of entire populations.

Availability of unregulated MNT manufacturing could create several serious problems. Criminal and terrorist activity would benefit from smaller, more capable products. Small, widely available, cheap surveillance devices would allow an unprecedented invasion of privacy by governments, criminals and neighbors. Cheap microscopic products can lead to widespread microscopic litter, with possible environmental or health consequences. Small self-contained foraging self-replicating systems ("gray goo") appear to be theoretically possible, and might be released by terrorists, saboteurs or even irresponsible hobbyists. Though probably less dangerous than all-out war with MNT-built weapons, such devices could be significantly more destructive than invasive biological species because they would have no natural enemies. Many of these problems can best be addressed by widespread environmental monitoring, but the required systems may not be deployed quickly or universally.

> ***"Since nanofactories will be self-contained, incredibly valuable and easily concealed, a black market in nanofactories would be difficult to prevent."***

Molecular manufacturing may cause substantial economic disruption. Several of today's sectors, including manufacturing, shipping and raw materials, would be disrupted or outmoded. Fully automated self-duplicating factories would reduce the value of both capital and labor, and drive down the cost of goods. Large disparity between cost and value would provide strong incentive for protectionism and anticompetitive policy, resulting in widespread black markets. The entertainment industry is already experiencing similar problems; MNT may

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extend them to most manufactured products.

Simplistic attempts to regulate MNT could create more problems than they solve. Attempts to restrict proliferation may generate oppressive or even abusive regulation. Today, billions of people live in sickness or poverty for lack of a few basic products like water filters, mosquito netting and computers. All of this would be easy to produce with MNT-based manufacturing, but recent US action blocking a WTO attempt to provide affordable pharmaceuticals to poor nations indicates that the same could happen with MNT. A population denied access to lifesaving benefits of cheap molecular manufacturing due to protectionist economic policy or paranoid security policy (or even just blatantly overcharged) would have a strong incentive to steal, duplicate or "crack" the technology. Independent MNT development programs multiply many of the risks, including the risk of necessary regulations and technical restrictions being bypassed. Since nanofactories will be self-contained, incredibly valuable and easily concealed, a black market in nanofactories would be difficult to prevent. Ultimately, control of the technology could be lost, and regions with excessive regulation may be sidelined.

In developing MNT, it may be that the safest course is a single, international development effort, leading to a technology that can be widely distributed and carefully administered—with tight technological controls in place to limit its use. This would provide an infrastructure for rapid humanitarian relief with basic products, profit-making with other products, and perhaps even arms control—if nations could be restrained from developing independent, unmonitored MNT capability. If this is in fact the best approach, the need for action is even more urgent. A nation with an entrenched MNT development program may be less likely to join or support an international development effort. It will not be easy to convince military and political leaders, captains of industry and environmental and social watchdogs that the best course of action involves giving up some control in order to retain some control.

MNT development appears inevitable for two reasons. The first is the immense utility of MNT. Even if public pressure prevented it from being used in consumer goods, various militaries would not hesitate to develop it as a tremendous aid to military capability. In conventional conflicts, the improvements in logistics, miniaturization, development and cost would give an overwhelming advantage to the possessor of such technology, both in preparation and in actual combat. The second reason is the increasing ease of development. Enabling technologies are improving each year. New families of structural chemicals are being discovered. New fabrication technologies, new nanoscale imaging technologies and increased computer power for mechanochemical simulation will rapidly decrease the difficulty of building an assembler—and thus a nanofactory. Today, a successful program might require billions of dollars and several years. A decade from now it might be possible for only $100 million, within the reach of many corporations and nations. At that point, if MNT is not already widely available, it will be developed in multiple labs around the world—and will be almost impossible to control.

By encompassing all phases of production from chemical processing to final assembly, MNT manufacturing can be far more flexible than any other single technology, with the possible exception of programmable computers. A few other technologies may be equally dangerous, but are easier to control. Nuclear technology can only be used for a few things—bombs, power generation, cancer treatment—so it has been possible for a fairly small international effort to keep control of various aspects of this technology. Biotechnology is flexible in its domain, but biotech products have been difficult to engineer. Conventional rapid prototyping systems will improve gradually; it will be a while before they can make complete products, and even longer before they can cheaply duplicate themselves.

A single technology with the programmability and speed of digital computers, the chemical flexibility of biotechnology, the military potential of nuclear technology or airplanes and the utility of very advanced rapid prototyping, will bring many changes. The variety of potential problems, in economic, military, political, humanitarian and environmental spheres, indicates that no simple solution can work. A balance must be struck between national defense and arms control; between capitalist practice and social needs and between unrestricted private use and oppressive restriction. These issues will not be easy to solve.

The final stages of development will occur too quickly for solutions

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to evolve. If a well-designed plan is not in place before this happens, one or more serious risks will very likely lead to military destruction, social or economic disruption or unnecessary human suffering on a large scale. Each major risk should be studied in detail. Public education and discussion should take place. Policy makers need to be informed. There is very little doubt that MNT manufacturing will be developed within the next three decades, and it may be as soon as ten years. It seems likely that some sort of international administration will be necessary. Any large administrative body, especially one requiring complex international cooperation, will take time to design, fund and create. All this may require more than a decade. A large international development effort may also be necessary, and would have to begin even sooner. These factors indicate that preparation for molecular nanotechnology should become a current topic in high-level policy and planning.

Author's Note: Chris Phoenix has studied molecular nanotechnology for the past fifteen years. Chris is the Director of Research for the Center for Responsible Nanotechnology.

1 "A Debate About Assemblers" http://www.imm.org/SciAmDebate2/index.html.

2 See http://CRNano.org/bootstrap.htm for the latest work.

3 For more extensive discussion of risks, benefits, and administration options, see http://CRNano.org/overview.htm.

PIR

Progress Report for FAS Learning Technologies Initiatives

By Marianne Bakia

Earlier issues of the PIR have outlined the need for a national initiative in educational technology research and development. FAS initiatives in this area include the Learning Federation and the Digital Promise, two projects that are promoting solutions to problems associated with under-investment. During our first phase of operation, we have been working actively to create a research roadmap that describes the types of learning environments that are possible, and outlines the types of projects that should be supported to achieve them. The roadmap is being developed through an iterative process that includes: literature reviews; interviews with researchers and practioners; and workshops that convene experts from universities, schools, government, corporate training organizations and software publishers.

Four workshops have been held to date. The themes of each addressed key processes of teaching and learning, including: pedagogy and instructional design; learner modeling and assessment; question generating and answering systems; and technical aspects associated with building robust and immersive simulations. These have been held at universities across the country from Seattle, Washington to Orlando, Florida.

Our most recent workshop focused on the theme of Learner Modeling and Assessment in May 2003. **Assessment** is defined as the measurement of learners' knowledge and skills, as well as the measurement of other individual characteristics that influence learning and performance, particularly general cognitive and metacognitive abilities, motivation and personality.[1] The terms "learner model" and "learner modeling" have mostly been used in the context of intelligent tutoring systems.[2] In an intelligent tutoring system (ITS), **learner modeling** refers to the process of generating and maintaining a continuous/dynamic model or profile of the learner and using the data for diagnosis, feedback, coaching and prescription of content during instruction.

Researchers at the workshop concluded that it is possible to create a class of software tools that can closely monitor a student's emotional state as well as their current level of understanding of any subject matter. This information could be used by another class of tools designed to customize instruction to improve rates of learning and depth of understanding, especially for complex topics. To accomplish these goals, our workshop findings identified five key R & D priorities:

- Map and reconcile disparate models of content expertise, competency and pedagogy;
- Automate modular assessment design, development, delivery and analysis;

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- Develop multidimensional learner models and measurement methods;

- Create web services infrastructure for integration of software applications and services.

In each of these areas, the emphasis is on developing scalable, interoperable, cost-effective software tools and systems that embody and automate practices and processes that are supported by theory and research.

We are now preparing for a workshop that will focus on the development of an integrated Learning Science and Technology R & D roadmap. This meeting will be held in Alexandria, Virginia at the Institute for Defense Analysis on July 24, 2003. The workshop will also examine the research management structure needed to implement the R & D described in the roadmap.

At the invitation of Chairman Upton of the House Subcommittee on Telecommunications and the Internet, Larry Grossman, FAS Board member, testified on March 25th on behalf of the Digital Promise Project in favor of establishing an educational trust fund that will provide substantial funding for the research and development of educational technologies. In his testimony, Mr. Grossman noted: " … if only the nation's system of education and training could begin to take effective advantage of the remarkable new information technologies, as the Defense Department, the press, and the private sector have already done, we could transform the quality and character of American teaching and learning as effectively as we've transformed the military, the media, and business." This testimony represents an important effort to increase congressional support for a national trust fund for driving educational technology innovation. The Digital Promise Project and the Learning Federation will continue to leverage their efforts to create an ambitious national endeavor.

Follow our progress via the Learning Federation link on the FAS website, www.fas.org and www.digitalpromise.org. We encourage your support for this important investment in the future of American education.

Author's Note:

Marianne Bakia is the director of the Learning Technologies Project at the Federation of American Scientists.

1 Snow, R.E., & Lohman, D.F. Implications of cognitive psychology for educational measurement. In R. L. Linn (Ed.), Educational measurement (3rd ed.). (Phoenix, AZ: Oryx Press, 1989), pp. 263-331; and Kyllonen, P.C.. Training assessment. In S. Tobias & D. Fletcher (Eds.), Training and retraining: A handbook for business, industry, government, and the military. (New York: Macmillan, 2000), pp. 525-549.

2 Shute, V., & Psotka, J. Intelligent tutoring systems: Past, present, and future. In D.H. Jonassen (Ed.), Handbook of research for educational communications and technology. (New York: Macmillan, 1996), pp. 570-600).

PIR

Challenging Conventional Wisdom on Arms Exports

By Tamar Gabelnick and Rachel Stohl

The following are excerpts from the conclusion of a new joint publication of the Federation of American Scientists' Arms Sales Monitoring Project and the Center for Defense Information on widespread misconceptions about conventional arms exports. The goal of the publication is to educate policymakers and the broader public about a set of myths that have been perpetuated by the defense industry and their allies in the government to justify a relaxation of export controls. The book, a set of papers written by outside experts and edited by Mses. Gabelnick and Stohl, also presents the potential risks of recent or potential changes to export controls, as well as suggestions for strengthening the export control system.

"The paradigm shift in US foreign policy created by the terrorist attacks of Sept. 11, 2001, means that most matters of foreign affairs are now defined in terms of the war on terrorism and continued threats to US security. As a result, arms export control "reformers," or proponents of sometimes far-reaching changes to the arms export system, are gaining greater resonance for their views by asserting that current restrictions on arms and weapon technology transfers are endangering US national security. The essence of the export reformers' argument is that the US ability to defend itself unilaterally or in coalition with allies depends on a healthy American defense industry, which in turn relies on large quantities of hassle-free exports.

But there is a paradox in the reformers' message that is rarely acknowledged: Even if arms exports do achieve some national security objectives in the near term, they can simultaneously decrease US security by contributing to the proliferation of US weapons and technology. This contradiction holds true for a wide variety of clients and the entire spectrum of weapons, from close European allies (because of the risk of diversion) to new allies in the war on terrorism; and from high-tech goods (both military and dual-use) to low-tech arms or spare parts.[1]

The tenuous benefits of export control reforms to national security is just one example of the way the public debate on arms exports has been manipulated by the weapon industry, conservative think tanks, and some senior officials in the Defense and State departments. With the exception of a few specialists in Congress and the General Accounting Office (GAO), most policy-makers seem to have accepted the assessment of the reformers that the export control system is broken and in urgent need of repair. No one is questioning whether the defense industry is presenting an accurate picture of export controls and their impact on international trade; whether the US government should be linking its interests so closely with those of the defense industry; or whether the policy proscriptions being put forward would be harmful to US national interests.

This book was designed to redress the one-sidedness of the debate by questioning the conventional wisdom about defense export reforms. We have examined in close detail the oft-repeated, but seldom analyzed, "myths" surrounding arms export controls. Whether or not one agrees with the conclusions of the chapters, it is essential that the content be discussed to form solid and safe policy. This book also adds to the debate by laying out some of the risks associated with recent or proposed policy changes. Moreover, rather than just criticizing the current proposals, the book proposes ways to strengthen the current system to make it more reflective of today's global security environment.

We believe that in order to develop sound export control policies, government officials need to seriously evaluate what the problems are with the current system and whether these deficiencies truly impact US national interests, or simply inconvenience the arms industry. If serious weaknesses in the system are identified, then policy-makers should find remedies compatible with the magnitude of the problems. In other words, those seeking to remedy any shortcomings of the arms export system should not throw the baby out with the bath water.

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Export Control Myths

This book lays out three main arguments that have been put forward

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by proponents of arms export reforms, repeated by the media, and taken at face value by policy-makers. First, reform advocates contend that the health of the defense industry relies on unimpeded access to foreign markets. A corollary to this belief is that the modernization of US military equipment depends on reduced restrictions on arms and technology transfers because this will stimulate technological innovations and lower costs through economies of scale. Second, reformers, especially in the Pentagon, state that arms exports are the best way to achieve interoperability with allied forces, and therefore placing unnecessary hurdles on exports will impede the US military's ability to work effectively with coalition partners. Third, State Department and other government officials allege that transferring arms to other governments is an effective way to win influence over their policies. In addition to these myths, conventional wisdom also suggests that even in our free market economy, government support of the defense trade is justified because of the arms industry's special relationship with the Pentagon.

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Risks Associated with Decontrol

Not only has the export control debate lacked sufficient analysis of the alleged problems being addressed, but it has also failed to include much assessment of the risks posed by current and proposed policy changes. Reformers pay lip service to the relationship between export controls and national security, but do not adequately lay out a picture of how a relaxation of export controls could affect US security. And they have virtually ignored how loosening controls could affect foreign policy goals, such as the promotion of human rights, democracy and regional stability. In addition, it is not surprising that the potential damage to congressional and public oversight is being left out of the debate largely dominated by the executive branch and industry.

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Recommendation

Advocates for changes to the defense export control system label their proposals "reforms," as if they were minor, but necessary, improvements to a flawed system. There are certainly some changes that could be made to the bureaucratic process – some of which, such as electronic license applications, are already being undertaken – that might make the system more efficient, and thus, effective. The problem with many of the proposals being put forward by the "reform" community, however, is that they tend to go far beyond the problem at hand. For example, since the process within the State Department is seen as being overly bureaucratic and slow, some reformers want to eliminate the State Department from the licensing process or allow industry to regulate its own exports.[2] Indeed, the myths reviewed in this book may have been constructed in order to justify policy solutions that largely surpass the actual problems being experienced by industry. Our first and most important recommendation, therefore, is for policy-makers to carefully analyze the defense industry's criticisms of the export control system to see if they truly impinge on US national interests, and then to evaluate whether the policy proposals are appropriate for those problems.

But policy-makers should go further than just maintaining current controls. "Reforming" the export control process should also mean strengthening the current US system and pursuing better multilateral controls. Especially in this time of heightened security risks, the question the US government should be asking is whether current controls will keep arms, technology and weapon components out of the hands of terrorists and away from unstable regimes. This means not only improving controls over US equipment, but ensuring that recipients of US defense goods and services share US values and protect sensitive US equipment. It means creating a truly transparent system so the public can provide essential commentary on arms transfers. And it means working with other nations to establish international arms control regimes of the highest quality.

...

Conclusion

The intention of this book is not to argue that expediting arms transfers will never lead to more interoperability, a healthier defense industry or closer ties with foreign militaries, or that these are not worthy goals. We simply maintain that there are different means to achieve these same ends, and that using relaxed export controls to advance these goals may create other, potentially more costly, problems. Therefore, the US government should think more carefully about the real need for structural changes to the export licensing process, the potential ramifications

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of such projects and possibilities for alternative approaches.

When conducting such analysis, US policy-makers need to recognize that it is simply not feasible to rely on increased arms exports to achieve certain foreign policy or national security goals. For example, one of the Pentagon's top priorities in reforming the export control system is to enable European allies to work more closely with American forces. But if the Pentagon truly wants to work with those countries on interoperability, it must acknowledge that many of them have weapon industries that they need to support. No amount of reduction in export control "barriers" will convince European states to buy only American, or even much more than they already are acquiring. The same may also be said about other importers, which for political or economic reasons may choose to go with other suppliers at times. The gap in defense capabilities with Europe is also linked to much lower European defense spending and investment rather than the limited constraints faced in buying US machinery.

Instead of focusing intensively on getting countries to purchase US weaponry, the US government needs to examine other ways to meet policy goals, such as interoperability, a healthy defense industry, protecting national security and enhancing its diplomatic strength. For example, interoperability can be improved through joint exercises and training, as well as through cooperation with allies on setting and respecting standards for interoperable equipment. The current high levels of defense spending in the United States would likely provide enough procurement and research and development funds to keep open lines of production and maintain skilled labor in the field. (The arms industry does not appear to be having any trouble meeting the recent rise in US procurement demand, which is one pretext for keeping open lines of production.) The way to make friends with both the governments and the peoples of foreign states is not through military aid, but with economic aid and a commitment to fair trade that would benefit the general population.

When it comes to promoting national security, the US government should be looking at ways to strengthen, not weaken, export controls, especially in these dangerous times. There have been several recent cases of individuals trying to smuggle spare parts to countries like Iran and companies providing critical technologies to China.[3] Any time a regulation is relaxed, or a weapon system decontrolled, the US government is forfeiting its ability to control who receives US arms and weapon technology or how it is ultimately used. As Sen. Tim Johnson, D-S.D., noted, "The lesson should be clear – to the extent that the US arms the world, it undertakes a risk that those weapons could be used against our own citizens." [4]

Cynics argue that globalization makes the spread of weapons and technology inevitable, and that US firms will miss out on valuable sales opportunities if the US government tries to unilaterally promote restraint. Rather than trying to reinforce multilateral arrangements, reformers seem to be asking the US government to give up the nonproliferation battle altogether. In other words, "If you can't fight 'em, join 'em." But arms control is too critical to take such a blasé attitude. There is also a vicious circle at play here: the easier it is to export arms and technology, the harder it will be to control their diffusion, and the more advocates for reform will say there is no point in having unilateral controls.

In addition, reformers fail to understand or admit that the symbolism of a US sales denial can be extremely important, regardless of whether the country in question is ultimately able to procure a similar weapon. The US government cannot be a self-proclaimed leader of democracy and human rights while at the same time arming governments that repress their own citizens. Nor can it effectively ask other exporting states to refrain from sales that threaten US interests (such as the alleged Russian sales of GPS jamming equipment to Iraq or Israeli AWACs to China), if it is simultaneously reducing its export controls or increasing sales that pose a risk to regional security. After the first Persian Gulf War, there was an international call for conventional arms control because of the damage to international security done by the 1980s arms build-up in the region. Perhaps the 2003 war in Iraq will also convince major arms exporters that careless exports can be exploited by certain states, leading to a severe threat to international security.

The value of arms export controls – be they unilateral or multilateral – is clear and compelling. The US government must stand behind the rules and laws it has carefully crafted over the past few decades. Though they could use some strengthening – especially on the normative side – they have served

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US interests well. It is hard to know whether controls will be missed until after they have gone. But when it comes to the international arms trade, the consequences of finding out may be too great to bear."

Authors' note:

Tamar Gabelnick was the director of the Arms Sales Monitoring Project at the Federation of American Scientists and now works as a consultant. Rachel Stohl is a senior analyst with the Center for Defense Information.

1 Army analyst Maj. Isaiah Wilson also notes the inherent conflict between the reformers' claim to be enhancing national security and the actual impact of such reforms. He also notes how the armed forces have been drawn into this process. "Perhaps the most tragic figures of all in this play are the US military services – forced to promote arms exports today out of economic necessity in hopes of acquiring the high-tech weapons systems they will need in the future to effectively secure and defend." Major Isaiah Wilson III, USA, Ph.D., "Today's Profits, Tomorrow's Losses: The Commercialization of US Arms Export Reform and its Implications on National & Regional Security," August 17, 2002, p. 3.

2 The first rumored proposal seemed to be put aside in favor of a reorganization of DTC at State. The second proposal, by the Center for Strategic and International Studies in "Technology and Security in the Twenty-First Century: US Military Export Control Reform," has not been rejected out of hand by administration officials.

3 "In September 2001, two individuals were sentenced in San Diego for their roles in an international conspiracy to illegally purchase Hawk missile components, fighter jet parts, and other military goods for Iran. In February 1999, Customs agents arrested two individuals for attempting to illegally export to China fiber-optic gyroscopes purchased from a US firm. These gyroscopes are critical in guidance and navigational systems for ballistic missiles and "smart" bombs. They are also used to stabilize weapons platforms." US Customs Service, "Snapshot of US Customs Strategic Investigations," Dec. 10, 2001, available at http://www.customs.ustreas.gov/hotnew/pressrel/2001/1210-02.htm. In March 2003, Hughes and Boeing paid a $32 million fine for the illegal transfer of satellite technology to China. State Department, "U.S Department of State Reaches Settlement with Boeing and Hughes," March 5, 2003.

4 "Congressional Record" Jan. 30, 2003, p. S1767-S1770.

PIR

How Well did TOPOFF 2 Prepare Us for Mitigating the Effects of a Dirty Bomb Attack?

By Jaime Yassif

The Department of Homeland Security conducted a simulated dirty bomb attack on Seattle as part of its TOPOFF 2 exercise that lasted for one week in mid-May. The exercise, the second in a congressionally mandated series that aims to troubleshoot and improve our ability to respond to a radiological attack, has been lauded by public officials for providing valuable lessons, but criticized by others who claimed that it was too scripted and too costly. Overall, the TOPOFF 2 dirty bomb simulation was successful at what it set out to do — namely reinforce emergency response capabilities. Its shortcomings have more to do with the aspect of radiological weapon mitigation that it left out — the longer term process of decontaminating and restoring urban areas to normal daily activity.

The most common critique of TOPOFF 2 has been that the exercise was too scripted. Emergency responders and participating federal, state and local officials knew weeks in advance the exact time and location of the mock radioactive "dirty bomb" detonation in Seattle, which allowed them ample time to study and practice for the simulation. In reality, critics argue, a bomb blast would be a surprise. Furthermore, senior decision makers such as the President, his chief of staff and his press secretary had made their decisions about the simulated attack ahead of time, and surrogates stood in for them during the simulation, issuing their 'decisions' from a playbook that was prepared in advance. This removed the element of decision-making under pressure, which critics claim should have been a component of the exercise.

While these critiques raise valid points and show that the Seattle dirty bomb simulation left room for improvement, TOPOFF 2 did provide valuable lessons about gaps in emergency response capabilities. In an interview with United Press International, Corey Gruber, the operation's associate director, said the most important difficulty identified by the exercise has been interagency communication. In addition to simple tasks, such as getting everyone on the same radio frequency, officials had to overcome communications challenges that arose when dozens of agencies, each with different sets of protocols and acronyms, tried to talk to each other and work together. Officials also learned that cordoning off a contaminated "hot zone" would have a profound effect on transportation, forcing buses to be rerouted around the area, commuter railways to be shut down and

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City of Seattle – Erik Stuhaug

Main site of simulated dirty bomb detonation.

How well did TOPOFF 2 prepare us? — Continued from Page 23

massive traffic backups on the local stretch of interstate highway. These lessons, along with mistakes made by emergency responders, helped accomplish precisely what the exercise was designed to do – identify weak points in the system so that they can be ameliorated.

The cost of the simulation—$16 million for the entire TOPOFF2 exercise—is also a source of contention. Some critics are questioning whether the expenditure was a worthwhile use of funds. However, it is important to bear in mind that in the context of Defense Department spending, this is a drop in the bucket. For a minute fraction of the $400 billion annual Defense budget, the TOPOFF2 exercise provided an effective means of reinforcing our consequence mitigation abilities in the event of a radiological or biological attack. Though the simulation left room for improvement, we should not be asking whether it was worth the money, but instead, why we are not conducting similar exercises for other types of threats.

The one aspect of the dirty bomb simulation that missed the mark was its limited time scope that only encompassed the first five days of the crisis. Many of the real difficulties of mitigating the effects of a radiological attack will come in the weeks, months and years after the event. Once the initial emergency phase passes, federal and local officials will still face the challenges posed by a public that is reluctant to return to their homes and offices. This could lead to a halt in daily commercial activity and steep drops in property values, ultimately resulting in severe economic damage. To minimize this potential damage, we should develop a comprehensive, long term decontamination strategy so it can be implemented as rapidly as possible in the event of an attack.

Getting off to a quick start with decontamination is crucial because it becomes more difficult with each passing week. Initially, the radioactive contamination will take on the form of fine dust particles loosely settled on the surfaces of buildings, streets and sidewalks. As time passes, these particles can be ground deep into porous surfaces or can react with organic compounds mixed in with chalks in concrete and petroleum derivatives in asphalt, making them much more difficult to remove. Removal of these firmly attached particles could require more invasive techniques such as the use of abrasives, chemical solvents and possibly the tearing up of streets and sidewalks.

In addition to easing the technical difficulties associated with cleanup, rapid decontamination will also reduce economic damage by restoring urban areas and facilitating the resumption of commercial activity.

Decontamination in the aftermath of a radiological attack will involve very different tasks than those required for the initial emergency response phase that was addressed by TOPOFF 2. The longer-term process of decontamination does not have to be executed with the same urgency, and therefore preparations can take on the form of planning, conducting studies and identifying useful technologies, as opposed to repeated drills and simulated scenarios of decision making under pressure.

At this point, the US does not have experience in decontaminating urban areas in the aftermath of a radiological attack. Our experience is limited to the decommissioning of industrial and government facilities, military decontamination exercises and cleanup efforts in the aftermath of the power plant meltdown in Chernobyl.

The national labs and private industry have developed a range of technologies that could be put to good use in urban decontamination. Though many of them were initially intended for small scale tasks, such as cleaning up laboratory hotboxes and nuclear reactors, some methods could be adapted for larger scale operations. We need to identify existing technologies that are appropriate for urban-scale decontamination and adapt them for these purposes.

Resources should also be allocated for developing new technologies that could be useful for urban-scale operations, such as alpha detectors that can scan large areas rapidly and effectively. Alpha rays are difficult to detect because they do not travel long distances, and they can be shielded by a barrier as thin as a sheet of paper. As a result, current detectors require slow, repeated scanning within close proximity of the source.

Still, no amount of technology can solve this problem unless it is integrated into a comprehensive decontamination plan that lays out which methods will be used in which situations, which tasks will be prioritized and who will oversee and carry out operations. TOPOFF

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2 demonstrated the utility of learning how the dozens of federal, state and local agencies involved in the first five days of a radiological attack will work together. The complex interagency relations that will come into play during longer term consequence mitigation should be worked out in a similar fashion.

TOPOFF 2 did set the stage for this type of planning, but more needs to be done. After the two initial days of activity in the field, three days were dedicated to a table-top exercise where participating officials focused on consequence mitigation strategies, and there was some discussion of the challenges posed by a contaminated water supply, sewer system and agricultural land. Participants also examine a range of existing radiation exposure guidelines — such as those provided by the Nuclear Regulatory Commision and the Environmental Protection Agency — to decide which standards to apply in mapping out areas that would require decontamination. But they did not look at how to implement these standards in carrying out a cleanup exercise. These exercises are a small step in the right direction, but the scope of consequence mitigation planning needs to be extended to the longer time scales of the weeks, months and possibly years that will be needed for full decontamination and economic recovery.

For additional information on this topic, see "U.S. Unprepared for 'Dirty Bomb' Aftermath", published in the April 28 issue of Defense News and available online at http://www.fas.org/ssp/docs/030428-defnews.htm .

Author's note: Jaime Yassif is a program assistant with the FAS Strategic Security Project.

FAS Website Gets a Facelift

by Peter Voth

The FAS web site has long been one of the premier destinations on the internet. Now, it's about to see its first major renovation since it was launched back in 1995, allowing us to take advantage of new technologies that were unavailable in the mid-1990s.

The most obvious difference will be in the site's look and feel, which has been completely redesigned. However, the most important changes are to the site's underlying structure.

Currently, the site consists of several thousand individual web pages that sit statically on our server. Whenever a change is made that affects more than one page – say, a link needs to be changed – each affected page must be located and edited. This arrangement makes maintaining the site a Herculean, some would say Sisyphean, task.

The new site will feature a database-driven content management system, which will allow staff to quickly and easily update web pages, enabling us to avoid the outdated pages and dead links that currently plague the site.

Over the coming weeks and months, the site will be migrating to this new system. Please be patient during this process – while we will make every effort to prevent access to your favorite resources from being disrupted, temporary difficulties may emerge. Please send any comments and questions to webmaster@fas.org.

Author's note: Peter Voth is the Webmaster for FAS.

Sample Screenshot

STAFF NEWS

FAS bids farewell to Tamar Gabelnick

On May 2nd, FAS bid farewell to Arms Sales Monitoring Project (ASMP) Director Tamar Gabelnick. After 5 years of tireless service and inspired leadership, Tamar left FAS (and the United States) to live in France with her husband, Pierre-Yves, and her 6-month-old daughter, Emma.

Tamar was appointed acting director of the ASMP just a few short months after she arrived at FAS in April 1998, and took over as project director the next year. Despite her relative inexperience with the arcane and opaque world of arms transfers and US defense trade policy, Tamar quickly established a reputation among academics, policymakers and the media as a knowledgeable and articulate source of expertise on the arms trade and US military aid. As a result, Tamar was able to generate and shape debate on these oft-ignored issues through numerous television and radio appearances, articles in leading scholarly and trade publications and through quotes in most of the nation's major newspapers. Her forthcoming book, entitled *Challenging Conventional Wisdom: Debunking the Myths and Exposing the Risks of Arms Export Reform*, (featured in this issue of PIR), epitomizes her knack for identifying important issues dominated by special interests and shaping the debate on them through timely and persuasive analysis.

Tamar's quiet charisma, passion for arms control and human rights and quick mastery of the export control minutia made her a natural leader in the community of NGOs that work on defense trade policy. Tamar led several coalition groups working on conventional weapons control, including the Arms Transfer Working Group and the Small Arms Working Group. By the end of her tenure at FAS, Tamar's expertise and leadership skills had attracted international attention. In 2001, she was invited to serve on a small steering committee of influential NGOs from around the world that is leading efforts to draft and promote an international Arms Trade Treaty.

While many people know and respect her work, only the few who had the privilege of working under her fully appreciate all of her many gifts - her warmth, her sense of humor, her inexhaustible patience, and her inclination to treat her employees as partners rather than subordinates. She will be both long remembered and deeply missed at FAS.

Tamar will continue to work as a consultant to arms control and human rights organizations from her new base in France.

...and Michael Levi

After two extraordinary years at FAS, Michael Levi has left his post at Strategic Security Project Director to become the Science and Technology Fellow in Foreign Policy Studies at the Brookings Institution. He leaves the Project dramatically reshaped to meet the requirements of the 21st century.

Michael's work at FAS has included landmark work on radiological weapons that was presented before the Senate Foreign Relations Committee, debunking longstanding myths about nuclear earth penetrating weapons, and providing a practical strategy for securing fissile materials. All of Michael's work has demonstrated not only his remarkable grasp of highly technical subjects, but also an ability to identify key security and poli-

STAFF NEWS

cy issues that can benefit from scientific insight. Michael communicates his perspective in a vigorous and energetic style that is accessible to a broad audience but never wavers in its technical precision. His articles in Scientific American and The New Republic, op-eds in The New York Times and other major papers and many appearances on radio and television have enlightened the national debate and built support for sensible security policy.

Everyone at FAS has learned from Michael and has enjoyed the excitement of working with someone whose learning curve often seemed perpendicular. We'll remember Michael's ability to challenge cherished beliefs of friends and opponents while keeping their respect. We'll remember his relentless search for practical, actionable ideas. We'll remember his unwavering search for what was honest, and what was right.

We wish him the best of luck at Brookings and hope that we can continue to collaborate.

FAS welcomes new Biology Issues Director

Stephanie Loranger joined the FAS team in March 2003 as the Biology Issues Director. At FAS, she will divide her time among several issues, including: the Digital Human, the Learning Federation, biological weapons, training and preparedness for WMD attacks and the responsible use of science and technology. Stephanie received her bachelors of science in biology at Boston College in May 1997. She received her Ph.D. in Biology and Biomedical Sciences with a concentration in Molecular Cell Biology at Washington University in August 2002. Her Ph.D. thesis titled: "The Role of Palmitoylation in trafficking of the t-SNAREs SNAP-25 and Syntaxin 11" combined cell biology and biochemistry with some neuroscience to elucidate the trafficking pathways of an important class of proteins involved in membrane fusion. Her work was published in the *Journal of Biological Chemistry*. Stephanie's work in graduate school was complemented with an interest in science policy, and she actively promoted a discussion of science and society at Washington University. She was also instrumental in encouraging and establishing career resources for graduate students and post-docs. Before joining FAS, Stephanie consulted for the NCI and EPA for 6 months. Stephanie remains a contributing member of both the American Society of Cell Biology and the American Association for the Advancement of Science.

FAS welcomes the following Nobel Laureates to the Board of Sponsors:

Riccardo Giacconi

Joseph Stiglitz

Paul Berg

Ferid Murad

Robert Furchgott

Daniel Tsui

FAS Public Interest Report

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In our continuing effort to provide FAS members with lively and timely articles in national security policy and other areas of science and technology policy, we are inviting members to submit proposals for articles in areas of interest to FAS members (maximum 1000 words). Selection of the articles is at the discretion of the Editor. Completed articles will be peer reviewed.

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