MINE DETECTION AND THE NEED FOR NEW TECHNOLOGY

Patrick Blagden

I am grateful for the opportunity to speak directly to American physicists by mean of this short article. I am not a physicist, so my article will be short on technical detail, and I can merely give a general outline of the problems encountered by various technologies used to date. In case any subscribers are interested in contributing to the fight against landmines, I have included some outline descriptions of what our equipment needs are, and how your ideas can be drawn in to our thinking. Right now, we need all the technological help we can get.

Like any industry, the mine action industry has many functions with as many definitions and titles. For brevity, I am expanding the word "mine" to cover all forms of explosive rubbish (sometimes known as unexploded ordnance or UXO), buried or on the surface, encountered by clearance teams during post-conflict mine action programmes. I am also abbreviating "mine clearance staff" to "deminers".

The post-conflict removal of unexploded landmines and other explosive materials is a continuing problem, which will plague many countries for some years to come. It is also an area where few major technological advances have been made since the 1940s. But why new technologies? Because mine detection and clearance is currently slow, dangerous and inefficient. It involves teams of men and women trying to detect the metallic components in a mine, which in some cases can be very small – indeed, some mines have been produced which have no metallic content at all. Otherwise, mines have to be detected by prodding the ground with sharpened rods like overgrown knitting needles, or by detecting the explosive vapour from the mines by the use of dogs. Prodding can be even more dangerous in hard or stony soil, when normal prodders have to be replaced by short bayonets for stiffness and strength. Many deminers have lost hands, faces and eyes during this process.

But why cannot you avoid the whole detection issue by destroying the mines in situ by rolling over them, hitting them flail weights, or crunching them up in some way? Because, alas, in practice these methods will not produce the accuracy of clearance required. Mines do not always explode first or second time they are pressured, especially if they have been in the ground for some time. Mines with bits knocked out of them are still effective if the firing system remains intact. Experience has shown that while machines can help to speed up the clearance process, the only truly accurate way of getting rid of all the mines is to detect and locate them first. Back to square one.

What do we want from new technologies? In the demining community we have analysed our actions to identify our most pressing needs, and these lie in two areas, both concerned with detection. Our studies have shown that we have two main detection needs – to identify reliably the location of each individual mine, and to locate where mines are not, a process called "area reduction".[1] Let us deal with the location of individual mines first.

Our desired detection tool is one that will give an accurate identification of a mine, as little as 4cm in width, buried up to 20cm in the soil. It must preferably give some idea of size, shape and depth under the soil, to allow better discrimination between mines and

[1] Mine Action Equipment: A Study of Global Operational Needs (GICHD Publication)

other battlefield debris. This identification must ideally be given in real time for ma-portable systems, and as nearly as possible in real-time for vehicle-mounted equipments. False alarms must be reduced to a sensible minimum, even in soils with metallic and other debris, metallic ores (such as laterites), roots and stones, at all conditions of soil humidity or water content. At least one version of this tool must be man-portable, robust, waterproof, light, easy and comfortable to carry and operate from standing, sitting, kneeling or lying positions. The size of the search head on man-portable units must not greatly exceed 12 inches or 30cm, for ease of operation in foliage, and no contact with the soil should be necessary during the detection process. It must preferably operate for an eight-hour day on an integral power source, and operate reliably at temperatures from 65^{o}C to - 20^{o}C. The tool must have a clear and unambiguous man-machine interface, and be usable, maintainable and field-repair-able by local deminers, who, whilst astute and well trained, may not be able to read or write. If the tool uses some form of radiation to "interrogate" the target, such radiation must not be harmful to the operator. It must be easy to maintain and repair, and be affordable. This is quite a wish list.

Such a tool would cause great productivity improvements under some conditions. A 100% improvement in false alarm readings can generate improvements of over 47% in productivity in areas where there are large numbers of metal fragments from artillery, mortars or rockets, or other battlefield debris[2].

Another version of this tool can be carried on a mine-protected vehicle, and used for the detection of anti-personnel and anti-vehicle mines on roads and tracks. Anti-vehicle mines are larger (some over 30cm in diameter), but may also have almost no metallic content. They may also be dug in deeper than 20cm. The vehicle-mounted detector will have no power consumption limitations, but will have to either respond almost immediately to the presence of a mine by stopping the vehicle, or to be fitted to an ultra-light vehicle, fitted with a target marking system which can roll over anti-vehicle mines without activating them. A clearance speed of 12kph or more is desirable. The other environmental and operating constraints for the man-portable systems will also apply, although there is less requirement for real-time detecion.

Now to detecting where mines are not. As early as 1996 we were concerned that too much time and expense were being wasted by clearing suspected mined areas, of which most of the area concerned was mine-free, with the mined area being a small proportion of the total. When mine clearance began in Bosnia, there were some 16,000 reports of mined areas, of which the majority had few, if any mines, but all had to be investigated. We therefore need a survey process, which can identify which parts of a suspect area are in fact mined. This requires "stand-off" identification of mined areas, a technological target very much more challenging. Attempts have been made to use satellite imagery, both radar and visible spectrum, but these lack the necessary resolution. Aerial imagery from airships has shown some potential, but identifying small 4cm plastic anti-personnel mine targets under 30 cm of grass, sometimes with trees or shrubs providing a further canopy, makes the challenge a truly daunting one. At present the job is done using sampling techniques, vapour-detecting dogs or rollers, but the technological challenge has not been met. Yet our studies have shown that an improvement of 100% in this area

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[2] ibid p51

will result of an overall improvement in productivity of over 42% across almost every operating terrain scenario[3].

What new mine detection technologies have we tried so far? To date, we have examined most areas of the energy spectrum, in the hope of finding something that will generate some response from a hidden mine. The ones offering most promise have been variations on metal detectors (which threaten to be useless against totally non-metallic mines and are generally slow to operate), ground-penetrating radars (GPR), Infra-red detection, various types of neutron energy bombardment, acoustic detection (a sort of land-based sonar), radio-frequency (RF) bombardment, other types of electrical energy bombardment, and explosive vapour detection. At a ground-breaking meeting in Stockholm in 1994, scientists and engineers met with deminers for the first time, and from this meeting, a chart was drawn up showing the most likely areas of technology to provide the advances the deminers were calling for. Unfortunately, the prediction of having new technology in field service in five years, ie by 1999, was never fulfilled. We are still about five years away from a fieldable new technology.

The technology showing the most chance of reaching the field has so far been GPR, but GPR has had difficulties in achieving the necessary soil penetration with a reasonable target resolution, although broad-band radars may be overcome this limitation. Fieldable man-portable GPR sets have been used in trials in Cambodia and Thailand.

Infra-red detection has not proved effective, again due the lack of resolution. In addition, the thermal difference induced by a small plastic mine laid just below surface level under a 30cm crop of grass is a daunting target for any detector, even given wide swings in daily temperature. Initial trials were better at showing recently dug holes where mines had been laid, but even these faded after 12 months, and in many cases deminers have to deal with minefields many years old. Pre-heating the target area might improve the signal, but at a considerable energy cost and administrative effort.

Various forms of active neutron interrogation have been explored[4], which can identify the presence of large concentration of Nitrogen by activation with thermal neutrons to achieve the generation of gamma rays. This area has been examined for some years, but no trial sets have been fielded.

In the field of RF detection, Nuclear Quadrupole Resonance is reputed to have the highest detection potential[5], but at the moment this technique works better for some of the more exotic explosives like RDX (cyclotrimethylenetrinitramine), rather than the cheaper TNT (trinitrotoluene), the more common explosive filling for mines. Some development is taking place in the military world, but this has not fed across to the humanitarian mine clearance community.

Acoustic sensors have apparently had some success, but no equipments have yet been sent for trials in any mine action programmes. It is possibly very difficult to detect small targets in dry stony or root-filled soil.

The detection of explosive vapours is another area where great advances have been made, but at present the sensitivity of such detectors still lags some orders of magnitude

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[3] ibid p51 and 52

[4] Forensic and Environmental Detection of Explosives; Jehuda Yinon, John Wiley & Sons Ltd p. 136 et seq

[5] ibid p. 118

behind the dog, which can apparently detect low vapour concentration levels down to 1 in 10^{-18}, which is better than current vapour detectors. It may be that other animals such as rats, bees or flies can also do so, but field trials have only been carried out with dogs and rats. The man-bee or man-fly interface will need some examination, as will the logistics of carrying out insect detection in places like Central Angola. Dogs and rats continue to show great potential, especially as there are now methods of bringing the vapours to the animals. The vapour sampling techniques and technologies used in this process will become even more vital if chemical or electronic vapour detectors become available with the right levels of detection and discrimination. This is in fact one area where new technologies can be said to used in the field, and where Research and Development are closely integrated with field operations.

You will note that in this article I have concentrated on detectors, and not on platforms. Over the last few years, the demining community have been offered robots (wheeled, tracked and legged), balloons, helicopters and other exotic vehicles. In most cases the designers seem convinced that all minefields are constructed on golf course greens and fairways – few even venture into the rough, let alone the bunkers. In my opinion, we must get the detection sensors right first, and then concentrate on the platforms that carry them. In practice, we have versatile, sustainable, low-cost two-legged platforms, which can get into every corner of a mined area in almost any terrain, which many vehicle-mounted machines cannot.

If the physics community have ideas on how we could improve our stand-off or close-in detection techniques, please let us know. We are not searching for "silver bullets", merely an incremental increase in our capability. Our overall aim is to speed up the demining process, and make it more reliable and cost-effective. We will do what we can to help your efforts: most of the GICHD staff have good contact with deminers world-wide. So how to approach the problem? Start by getting to know the mine detection situation as well as possible, attend demining syposia, visit some minefields (I recommend conducted visits only, please!) or look at photographs of suspected minefields on the GICHD website, http//www.gichd.ch/.

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COMMENTARIES

The Moscow Treaty Will Not Eliminate Weapons or Reduce Arsenals

Joseph Cirincione

When even the *New York Times* gets it wrong, you know there is deep confusion about the arms control treaty Presidents Bush and Putin will sign this week—inspired in part by the administration's hyperbole. Contrary to the *Times* reporting, the new treaty will *not* "winnow their nuclear arsenals by two-thirds in the next decade" or "eliminate thousands of nuclear weapons," as an oped mistakenly said. Ten years from now, when the treaty concludes and expires, the United States and Russia will each have over ten thousand nuclear weapons—exactly what they have today.

How can this be? You have to pay attention to the fine print in this agreement. The new treaty reduces only the number of "operationally deployed strategic" warheads. These are the nuclear weapon on missiles and bombers that fly over 5,500 kilometer and have been the subject of all previous strategic reduction treaties. But strategic weapons are just the tip of the nuclear iceberg. The U.S. and Russia both have thousands of tactical nuclear weapons—with warhead just as large but which are designed for battlefield or shorter-range use—that are not included in the treaty.

Both nations also have thousands of warheads in storage in various state of readiness, from ready-to-go, to "some assembly required," to thousands of plutonium cores stored outside weapon assemblies. Compared to these bombs atop missile ready to fire in 2-3 minutes, these may seem less of a threat. But if Iraq had even one of the thousands of weapons in U.S. and Russian storage, it would be an international crisis.

The treaty eliminates no weapons. Both nations will slightly reduce the number of missiles and bombers, but this is from previous plans, not from treaty requirements. The treaty will limit the number of nuclear weapons on these missile and bombers. But the actual weapons will be moved from one spot to another, not eliminated—and they could be moved back. *Time* magazine and the *Washington Post Outlook* section are among several publications that have looked deeper into the agreement and the larger, nuclear arsenals untouched by the talks.

These stories and others help explain what the treaty will not "liquidate the legacy of the Cold War" as President Bush has claimed. Ten years from now the U.S. will still field a large, dispersed force of strategic weapons whose only justification is to target and destroy Russian military, industrial and political sites.

The warheads will be deployed on:

14 *Trident* SSBNs,
500 *Minuteman III* ICBMs,
76 B-52H bombers, and
21 B-2 bombers.

Some warheads removed from delivery vehicles will be dismantled, but the majority will be maintained in a "responsive force" or stockpile for potential return to delivery systems on short notice (weeks or months). They will be stored apart from delivery vehicles but maintained in a ready-for-use configuration with tritium and other limited life components installed. There is also and will remain an inactive stockpile of warheads that do not have limited life components installed, and may not have the latest warhead modifications. These warheads are kept as possible replacements for active warheads and as a "hedge" against the discovery of a problem.

The large question is why are we keeping this large a force? Does it really reflect the new relationship with Russia? In fact, there is no strategic justification for maintaining thousands of weapons on high alert and a reserve force of thousands more weapons ready for re-deployment other than to target Russia. Other target sets detailed in the recent Nuclear Posture Review are added on to, not substituted for, the Russian targets.

The real mark of a new relationship with Russia will not be when we no longer sign arms control agreements, but when we no longer maintain elaborate plans to target and destroy Russian cities—and when Russia no longer does the same for U.S. cities.

United States Nuclear Weapons, from 2012

Category	**Number of warheads**
Operationally deployed force	1,700-2,200
Missile warheads on 2 Trident Submarines in overhaul	~240
Strategic missile and bomber warheads in responsive force	~1,350
Nonstrategic bombs assigned to US/NATO conventional/nuclear capable aircraft	~800
Nonstrategic sea-launched cruise missile warheads retained in the responsive force	~320
Spare strategic and non-strategic warheads	~160
Intact warheads in the inactive reserve force	~4,900
Sub-Total Intact Warheads	**9,470-9,970**
Stored plutonium and HEU components that could be reassembled into weapons	5,000
Total of All Warheads and Components	**14,470-14,970**

Source: Natural Resources Defense Council "Faking Nuclear Restraint" 13 February 2002, analysis of the Nuclear Posture Review

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ENERGY BILL BASICS

Tina Kaarsberg[1]

For the first time since 1992, the House and Senate have both passed comprehensive energy legislation. As of this writing the Senate had already named its conferees[2], but the House, which has more committees of jurisdiction, had yet to name theirs. Since the House and Senate energy bills are so different, the conferees could produce a document that bears little resemblance to either bill. In those areas where the bills are similar, however, the legislation is likely to emerge from conference largely unchanged. For example, both bills include provisions relating to the management of R&D at the Department of Energy and general support for increased energy efficiency in buildings, consumer goods and industry.

As I read through the two bills, I was stuck by the difference between the simplistic press coverage of the bills (yes/no on ANWR[3] and CAFÉ [4]) and the depth and breadths of the actual bills. The House legislation, H.R. 4, which was passed on August 2, 2001, is 530 pages long. Its official title is a bill to " To enhance energy conservation, research and development and to provide for security and diversity in the energy supply for the American people, and for other purposes." The Senate bill (the original S. 517 replaced the House H.R. 4 as an amendment) which passed on April 25, 2002, is 976 pages long and is entitled *"the Energy Policy Act of 2002."* The Senate bill, which was passed after the California electricity crises and Enron scandal, include major electric industry restructuring provisions including a repeal of PUHCA[5] and amendments to the Federal Power Act and to PURPA[6]. No such provisions are in H.R. 4. The post- September 11th Senate bill also has an entire title devoted to "critical infrastructure protection." The House bill has many more detailed provisions relating to energy technologies. But don't take my word for it—both bills are on the Web. The House bill is at: http://thomas.loc.gov/ once you get to this site, enter "H.R. 4" in the bill number search block, hit search, and the version of H.R. 4 for the House is the "SAFE Act of 2001 (Engrossed in House)" version and the Senate bill is at

http://energy.senate.gov/legislation&docs/pdf/107-2/energy_bill/hr4_esa.pdf

1146 words

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[1] As of June 3rd, 2002, Dr. Kaarsberg, who had been at the U.S. Department of Energy, will be joining the Majority staff of the House Science Committee, Energy Subcommittee.

[2] Senate Conferees are Bingaman; Hollings; Baucus; Kerry; Rockefeller; Breaux; Reid; Jeffords; Lieberman; Murkowski; Domenici; Grassley; Nickles; Lott; Craig; Campbell; and Thomas.

[3] ANWR stands for Artic National Wildlife Refuge. The Bush Administration and most Republicans support opening ANWR to oil drilling. The environmentalist community opposes this drilling.

[4] CAFÉ stands for Corporate Average Fuel Economy. Environmentalists want to increase the required fleet efficiency—Auto industry supporters oppose this approach as too costly.

[5] PUHCA stands for the Public Utility Holding Company Act of 1935.

[6] PURPA stands for Public Utility Regulatory Policies Act of 1978,

EDITOR'S COMMENTS

In addition to the usual book reviews, we have recently published material on cinema and theater in the context of "physics and society", e.g., Michael Frayn's play "Copenhagen", and Sylvia Nasar's biography "A Beautiful Mind. I wonder how many of the readers of this journal have attempted to use theater, cinema, or other popular media to teach or otherwise deal with contemporary problems and opportunities of science and society. I would welcome the opportunity to publish reflections on such attempts in this journal. Perhaps we could even devote an entire issue to the intersection between arts and humanities and science. So this is another call to our membership to submit material - either in the humanistic mode mentioned above, or in the more "traditional" mode of "physics and society" issues- for publication in future issues of "Physics and Society".

Among the more" traditional" interests of the Forum, and this journal, has been the question of nuclear weapons and how to deal with them – are they just another class of weapons, in spite of their major non-Newtonian aspects, or are they somehow "transcendental"? The main thrust of previous American Administrations has been the latter –the use of nuclear weapons is to be contemplated only in situations threatening the continued existence of the nation. There are some indications, in the actions and documents of the present Administration, that they do not share this view. Von Hippel and Cirincione explore this topic in this issue. Also of continuing interest to our readers are the politics and technology of energy and nuclear power, discussed here by Kaarsberg and Ahearne (and in the previous web issue by Chang).

Land mines are definitely "conventional" weapons but their use and disposition is still devastating to many of the world's peoples. As Blagden points out here, they also represent a challenge to the world's physicists. Sen and Woodfin also discussed (this challenge, in our previous web issue.) A more recently recognized challenge for physicists is how to deal with terrorism, discussed in this issue by Fainberg (and in the previous issue by Cobb and Koooonin). Newtonian gravitation is no longer at the forefront of physics research but its application is the basis for another "physics and society" concern – the possibility of war in space. This subject is examined, in this issue, by Sessler and myself. Also of considerable concern to our members should be "who are we" and "how do we get to be physicists", questions which are examined by Pugel and Urry. Finally, Brecher has a look at technology, a subject that can never be far from the mind of the physicist.

I hope you enjoy this "hard copy" issue of P&S, as well as the previous "electronic copy" issue. Have a good summer while you read them. And please remember to participate in the Forum: attend its meetings, participate in its committees, and submit materials to its journal.

THE ROLE OF PHYSICISTS IN COUNTERTERRORISM:

Tony Fainberg

Background

I began my interest in the role of technology in counterterrorism in the late 1980's while working at the Congressional Office of Technology Assessment (OTA), which had a good run of twenty years before being closed by Congress in 1995. It had occurred to me that science and technology could do a lot to help in this area. Although some research and development projects had appeared here and there in various government agencies, I was not convinced that the overall effort was as large or as coordinated as it should be. This still may be the case.

Following the destruction of PanAm Flight103 over Lockerbie, Scotland in December 1988, I was able to persuade my colleagues at OTA that technology and counterterrorism was a fertile field for study, and, within a couple of years, we produced a couple of volumes on the federal effort to apply technology to counterterrorism. The areas covered included not only aviation security, but also chemical and biological terrorism (which had been insignificant up to that point), communication and organizational issues, explosives detection technologies and a number of other areas. Up to that point, not too much work had been done to survey what needed doing and what was being done to apply technology in the war on terrorism: a war that did not begin in 2001, but that was ongoing even in the late eighties. Some of the suggestions made in the work were acted upon. Many findings and conclusions are still applicable.[1]

In the nearly fifteen years since, terrorist attacks have increased in effectiveness and scope, if not in raw numbers. The federal reaction, most easily measured in dollars, has also ramped up, although usually in stuttering steps, or perhaps I should say, the federal effort has evolved in a mode approximating punctuated equilibrium. There were quantum leaps in funding immediately following major events, such as Lockerbie, the (non-terrorist) crash of TWA flight 800 in 1996, and, most obviously during these past months. In between, funding stays stagnant, more or less constant, until the next event.

As fiscal points of reference, I offer the following: the budget of the Aviation Security Research Laboratory in Atlantic City, which had a budget of less than $10 million per year in 1988, now is envisioning a funding level well in excess of $50 million for fiscal year 2003. Similarly, the Technical Support Working Group, which is an interagency group that funds counterterrorist technology applications that might otherwise fall between agency cracks, was staggering at a level of around $2 million per year in the late 1980's and was in danger of extinction. It now has a budget in excess of $80 million.

Of course, in the acquisition mode, things are even clearer. For years, the federal government was not in the business of buying security equipment for airports, and air carriers flatly refused to put money into this unproductive activity, since, as was frequently asserted, there was no domestic terrorist threat to civil aviation in this country. After TWA 800 in 1996, with the appearance of yet another Presidential Commission, this one headed by Vice-President

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[1] U.S. Congress, Office of Technology Assessment, *Technology Against Terrorism: The Federal Effort*, OTA-ISC-481 (Washington, DC: U.S. Government Printing Office, July 1991) and U. S. Congress, Office of Technology Assessment, *Technology Against Terrorism: Structuring Security*, OTA-ISC-511 (Washington, DC: U.S. Government Printing Office, January 1992).

Gore, the government decided for the first time to pay for the deployment of massive amounts of security equipment at airports. The majority of these devices were of two basic types: a CAT-scan-based explosive detector that cost about $1 million each (exclusive of installation), and trace chemical detectors, costing about $40,000 each, that were usually placed at passenger checkpoints to test carry-on items for explosives residues. For the first few years after TWA 800, over $100 million/year was applied to these acquisitions. Each year, however, it became more and more difficult to sell the idea of this deployment, since there had been no real evidence of a major terrorist act against domestic civil aviation for quite a while. The resident memory time of many decisionmakers was not all that long.

Now, of course, things are much different. In the wake of much discussion over many years, the terrorist events of 2001 impelled the Congress to federalize the security screening force at airports (it had been mostly in the hands of private contractors to the air carriers), and to deploy enough explosive detectors to check everyone's luggage in the United States, by the end of the year. Hundreds of CAT-scan-type units and several thousand trace detectors will likely be deployed. For comparison, since 1996 until 9/11, given the fiscal ceilings, only about 150 of the former and about 1000 of the latter had been deployed. The total bill for aviation security for the current fiscal year will be somewhere between $2 billion and $6 billion, depending on how one counts. Much of this will be a one-time capital expenditure, but one may expect yearly bills at least of the order of a billion dollars or more for the indefinite future, especially considering the large numbers of additional screening personnel now on the federal payroll for the first time.

All this may give you an idea of where the public interest is now in the field of transportation security. There are other topics within transportation security that I have not yet touched upon, including future threats in the realm of weapons of mass destruction, which we have to anticipate and deter. There will be a major effort to focus on other modes of transportation in addition to the obvious major target, aviation. There are operations research issues in designing security systems that need serious and inventive work. And there are a host of new communications and cyber-based issues that also require innovation and creativity.

This brings me to the major topic of the discussion: namely what can physicists do to help? And, as a point of reference, I would like to mention that my colleague Fred Roder, a physicist now at the TSA, was responsible for the conception, development and initial production of the CAT-scan explosive detectors: a (nearly) lifetime project that for many years no one thought would succeed.

Technical Tasks

It might be useful to describe some of the research and development tasks that remain in transportation security. Some of these are well-known and obvious, others have been less discussed and less worked on. The list is not all-inclusive, but will give you a flavor of the main directions of effort.

Improve explosive detection for

- Baggage
- Carry-on
- Cargo
- Persons

The issues here are the canonical ones: detectors that are faster, cheaper, smaller, and, above all, have higher efficiency and lower false alarm rates. With regard to detection on people, in particular, there are also issues of privacy and civil liberties, which are not to be discarded for the convenience of the engineer or security designer. While we may have more latitude than before the terrorism of last year, there are still limits of intrusion, beyond which we are not allowed to go without serious cause.

Improve access control at airports.

For years, there has been a problem in maintaining the proper control to access to the "sterile area" of an airport. A related issue is the confidence we may have in the background checks now to be performed on those with access to aircraft.

Investigate chemical and biological detection.

Investigate detection of nuclear and radioactive material in all modes of transportation.

The reasons for the above are obvious and have been much reported in the press. Whereas the nuclear threat may be less immediate, one cannot completely dismiss it in the longer term. The radiological threat, whereas rather less serious than other weapons of mass destruction (WMDs), is probably more immediate: virtually any effective organization can obtain highly radioactive material. Other areas of technical interest:

Perform vulnerability analyses of systems and subsystems that form part of aviation security, both domestically and internationally.

Work on integrating security systems at each site.

Continue to apply human factors science to transportation security issues.

Improve security communications, including between aircraft and ground.

I think most of these are self-explanatory: they involve more systems engineering and psychology than hard science, but are no less vital.

There are additional technical studies of aviation security technologies that are easily accessible, many of them authored by panels of the National Academy of Sciences, under contract to the Federal Aviation Administration.[2] These provide many details on a wide variety of technical approaches to the issue.

Potential Roles for Physicists

The above list, although not exhaustive, clearly implies many opportunities for physicists in their direct areas of expertise but also in analytical areas that may not be related to physics, but where the sort of logical analysis and understanding that physicists do well, can be applied. There is at least as much use for a physics background, for example, in doing a systems analysis of a complex security entity as there is in attempting to predict stock options behavior, to cite just one area in which physicists have been quite active lately.

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[2] There are several reports since 1993 that may be found at http://www.nationalacademies.org. *Detection of Explosives for Commercial Aviation Security* in 1993 was the first; *Assessment of Technologies Deployed to Improve Aviation Security* in 1999 is the most recent broad review from the Academy. Additional studies that cover security issues in other transportation modes as well as aviation can be found at the site of the Academy's Transportation Research Board at http://www4.trb.org/trb/homepage.nsf/web/security.

The area about which I am most familiar is aviation security. I have worked in this field from without and within, on and off, for some 13 years. Here, the bulk of the technical work has been done by a technical center in Atlantic City that does some lab work and some contracting. At the Center, which will probably be expanding, there is a staff of some 70 people, of whom about 15 are Ph.D. scientists and engineers. Disciplines run from physics to industrial psychology. The quality of the staff is high; remarkably so, for a small center that is almost unknown outside the limited scope of actors in the field. At the TSA headquarters, there is an additional staff of competent scientists and technology integrators.

One point: there is a need for expertise in biology, since awareness of the biothreat to civil aviation is recent. The anthrax letters reminded many that civil aviation could become a target of bioterror as well. Indeed, in the Aviation and Transportation Security Act of 2001, there is a provision requiring the TSA to consider putting bioterror countermeasures in place. I can imagine a potential role for biophysicists, of course, particularly in the area of improving biodetectors.

What are the other technical elements in the Department of Transportation that may be dealing with technical issues related to counterterrorism? Two important ones are the Volpe Transportation Systems Center and the Coast Guard. Neither has done too much work in the terrorism area to date, but this is changing now. Volpe has, in fact, worked in the explosives detection area for a number of years. Additionally, it has worked on vulnerability analyses of transportation facilities and nodes, but the main emphasis in the past has been on innovation in transportation and safety, health and environmental issues related to transportation. Now, Volpe is extending its efforts to responses to chem and bio terror, preparing information and courses for first responders in areas related to transportation. Volpe is also developing expertise in biometrics, and perimeter security. The Coast Guard has focussed primarily on smuggling and occasionally on specific military requests, but is now turning to vulnerability analysis and the threats from weapons of mass destruction. Both entities, clearly more concerned with counterterrorism now, may be expected to contribute significantly to R&D in this field.

In summary, there are physics and physics-related problems in transportation security that are crying for innovative ideas and new sets of eyes and brains. In addition, there are engineering and systems problems that can benefit from physicist-like techniques of analysis and study. Further, counterterrorism and technical responses are likely to be growth areas for a while. Moreover, work in this field can yield the satisfaction that one is doing work that is relevant (remember the 60s?), important, and that may save many lives, as well as enhance the national security. I commend this sort of work to your consideration, either as a newly-minted PhD, a mid-career physicist, or a senior physicist. Work can be done in many modes: as a government employee, as a consultant to government, as an employee of a private corporation, or even as a constructive and informed outsider. Academics can participate under grants or contracts, so the effort devoted to this endeavor can be part time. Or, one can immerse oneself entirely. The range of options is open.

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NEWS FROM THE CHAIR

The Forum on Physics and Society has been granted its own seat on the APS Panel on Public Affairs (POPA), the main public policy body of APS. This should be a synergistic relationship, since the areas in which POPA acts are often those in which the Forum is deeply involved. This new relationship will keep both sides better informed, and help the APS tap the rich talent and expertise of Forum members.

The Forum's first representative to POPA, Aviva Brecher, was appointed at the end of 2001 for one year. At the end of this summer, the Forum will hold its first election for POPA representative. Requirements for this new position include membership in the Forum for at least 4 years, time to attend the 3 yearly meetings of POPA and participate in its activities, a commitment to regularly communicate with the Forum leadership and membership, and a willingness to listen, learn, and bring the best of oneself to the job. This position is a 3-year term, and the elected member will also serve as a member of the Forum's Executive Committee. This will be an all-electronic election, for which Forum members will receive an electronic reminder. The Forum's Nominating Committee, chaired by Daniel Kammen, is currently taking suggestions for nominees for this new position. He can be reached at < kammen@mindspring.com>. The Forum is proud to have permanent representation on POPA and looks forward to a long and fruitful relationship.

On a less joyful note, the Forum announces the departure of Marc Sher from its leadership, after a decade of extraordinary service. Marc, like many of the Forum leaders, was personally recruited, and once on board, made tremendous contributions. He served three years on the Executive Committee, three years on POPA, was news editor and electronic communications editor of Physics & Society, developed the first Forum webpage, and started the first Forum electronic elections, paving the way for electronic elections at APS. In every position he served with energy, enthusiasm, and skill. He is always a pleasure to work with, and an inspiration to all who interact with him. It is with immense gratitude that we bid Marc farewell from our leadership, with the hope that he will return at some later time.

As the new chair of the Forum on Physics and Society, I am excited and a bit awed by the task before me. The membership of the Forum has broad interests, from Missile Defense, to Renewable Energy, to Climate Change, to Science in Commerce and Foreign Affairs, just to name a few. Each year we try to address some of these areas in both our newsletter and in our sessions at the APS March and April meetings, as well as other timely issues where science and society intersect. We can never deal with all the issues the membership would like, nor can I dream of being able to lead our efforts in so many areas. But I don't need to, because the heart and soul of the Forum is its very impressive Executive Committee. We are also supported by talented and knowledgeable people at APS. I look forward to a productive year, and hope you will participate in our activities.

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REVIEWS

Megawatts and Megatons: A Turning Point in the Nuclear Age?
by Richard L. Garwin and Georges Charpak (Alfred A. Knopf, New York, 2001, 412 pp.) $30.
ISBN 0-375-40394-9

Two documents by the Bush administration have focused media attention on nuclear issues. The publication in May 2001 of *National Energy Policy* (currently the subject of a General Accounting Office suit against the administration to gain access to information about the meetings leading up to the study) advocated that "the President support the expansion of nuclear energy in the United States as a major component of our national energy policy." Whereas the Clinton administration's attitude towards nuclear energy ranged from hostile to grudgingly neutral, the current administration has endorsed nuclear energy. The American utility industry has been slow to follow this lead. In addition to *National Energy Policy*, the administration has sent to the Congress a long-delayed recommendation to go forward with the proposed Yucca Mountain geologic repository for high-level radioactive waste. These actions have stirred up the debate on nuclear power.

Similarly, the recently leaked *Nuclear Posture Statement* has reopened debate on the role of nuclear weapons in the post-cold war world, including issues surrounding the Comprehensive Test Ban Treaty (CTBT), the need for testing of nuclear weapons, and the development of new nuclear weapons. Thus the current administration's documents, one public and one leaked, have laid a foundation for serious discussion of nuclear power and nuclear weapons. Richard Garwin and Georges Charpak's recent book will be a significant help for those trying to understand the technical and policy issues.

Richard Garwin is an American theoretical physicist who has been involved in US science policy since working in the Manhattan Project. He is a member of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. Garwin, well known to scientists who follow public policy issues, received the American Physical Society's Szilard Award in 1976. Georges Charpak is a French experimental physicist, and a member of the French Academie des Sciences and the US National Academy of Sciences. He received the 1992 Nobel Prize in physics.

Garwin has advised the U.S. government for many decades on technology and nuclear weapons. This book addresses comprehensively both nuclear power and nuclear weapons. Unlike many articles and books on these subjects, this was written by authors who have first-hand and extensive experience with the technologies and the policy debates. The writing is clear, presents the information, and allows the reader to reach conclusions as to the weight of evidence. Enough data is presented so the reader can do back-of-the-envelope calculations to check some conclusions, such as the relative risks of nuclear and coal plants. Although the authors are, I believe, favorable to nuclear power, they do not support one of the beliefs of most nuclear power advocates, namely that reprocessing should be pursued. Reprocessing leads to separating the plutonium out of spent fuel. Their lead-in to this issue: "For an engineer, a ton of plutonium can produce one gigawatt of electricity for a year; for an economist, a ton of plutonium has a negative value of $25 million (this is the additional expenditure required to enable a ton of plutonium and 20 tons of MOX fuel to be sold at the same price as 20 tons of enriched uranium fuel of the same energy value in a light-water reactor); for Saddam Hussein, it can make 200 nuclear bombs."

The authors also treat nuclear fusion, presenting a primer on the topic, and they review many types of reactors, including boiling water, pressurized water, CANDU, gas reactors, and breeders. They do not advocate breeders. The fuel cycle is addressed, including reprocessing and waste disposal. Energy policy issues are treated, including global warming. They favor renewables and energy efficiency.

The book treats nuclear weapons in detail (restricted, of course, by classification) and introduces those unfamiliar with the policy issues to “sufficiency,” the role of the International Atomic Energy Agency in non-proliferation, the politics of the CTBT, and the history behind US and French nuclear forces. They make clear that making a nuclear weapon is not easy and that the critical step is getting the fissionable material. The current debate on how to dispose of weapons plutonium is treated as a significant issue. They address the dual-track approach (vitrification and MOX) advocated by the Clinton administration, and the “spent fuel standard” introduced by the National Academy of Sciences. Garwin has long been an advocate of arms control. They write “the threat to the nuclear forces themselves, before they could be launched and before they could reach their targets, contributed to an inflation of strategic nuclear forces in the United States and the Soviet Union that went beyond all military logic.” They conclude “it is appalling to the authors that the literate peoples of the world do not take feasible steps to reduce the threat of 30,000 or more nuclear weapons still present in the world.”

The book is an updated version of a 1997 French volume by these authors, *Feux Follets et Champignons Nucleaires*. It can usefully be read by anyone interested in either nuclear power or nuclear weapons policy. Although in parts the book does require following technical details, it should be read by new Congressional staff members and other newcomers to these debates to learn about these tough issues.

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Space Weapons, Earth Wars
by B. Preston, D. Johnson, S. Edwards, M. Miller and C. Shipbaugh,
Project AIR FORCE, (RAND, Santa Monica, 2002), pp. 201, ISBN: 0-8330-2937-1

This book coldly, very coldly, examines the subject of weapons in space. The book--really a report to the Air Force--describes the various types of space weapons, how they might be deployed, and how they might be employed in battle. It describes how these weapons might be acquired (by the US and/or other nations) and, in a final section, it describes the advantages and limitations of such weapons.

The report initiates its discussion by noting that it is the Air Force's policy to fully use space for national security. And "fully" means, it notes, "beyond intelligence, surveillance and reconnaissance, warning, position location, weapons guidance, communications and environmental monitoring." In short, real weapons. The report states that it "does not present an argument either for or against space weapons but instead describes their attributes and sets out a common vocabulary." But it does observe that "although there is currently no compelling threat to US national security that could not be addressed by other means, the United States could consider space-based weapons as a component of its vision of global power projection for 2010 and beyond." The report then simply goes on to analyze, in detail, space-based weapons.

The report considers directed energy weapons (lasers and particle beams), kinetic energy weapons, and space-based conventional explosives. (Weapons of mass destruction are prohibited by treaty, and the now-defunct ABM Treaty prohibited missile defense in space.) For each, it describes in considerable detail the weapon's uses, time lines, and absentee ratios.

For example, the report considers space-based lasers employed for boost-phase missile defense. Taking a hydrogen fluoride laser of reasonable strength, and a reasonable kill criteria (that however might be ten times more demanding if the missile is hardened), they then calculate how many missiles one laser can destroy. There isn't much time for a kill as the laser doesn't penetrate below 15 km because of atmospheric effects on the laser beam, and the missile burns out at about 50 km. Since the laser mirror must slew from one target to another, a laser can only take out three missiles; four missiles would saturate a laser. In any constellation of lasers, most of the lasers are on the other side of Earth, so the absentee ratio is 24; that is, 24 lasers would be needed, and more if you want the saturation to be higher. The fuel needs are about 200 kg per kill and it takes 25 kg to orbit 1 kg. Furthermore, but not commented upon in the report, the war head keeps going with somewhat reduced range, so an ICBM launched from North Korea and aimed for a ranch in Texas might come down in San Francisco.

This example leads one to respect the many detailed calculations that make this a valuable report, because the report is meant to turn loose talk into serious consideration. It seems to me that such details would lead any reasonable person to dismiss lasers for boost phase defense. However other uses of space weapons, such as having cruise missiles launched from satellites, delivering an explosive warhead to destroy large naval ships or highly defended surface targets in (say) 30 minutes seems possible employing only 5 satellites. Now the cost is about 50 kg for every 1 kg delivered, but the appeal to the military of being able to project power anywhere in the world on a half hours' notice must be very attractive.

In the sections on acquisition of space weapons, the report gives separate consideration to several alternative scenarios: a US decision that is either deliberate or incidental, a decision that is either incremental or monolithic (all-at-once), a decision that is multilateral (in concert with other nations) or unilateral, etc. This discussion is extensive (almost 50 pages) and exhaustive. In the concluding section both the advantages and the limitations (large numbers, logistic expense, legal aspects, predictability of orbits, etc.) of space weapons are reviewed.

Although I couldn't find a discussion of this point in the report, it seems to me that, if you found a weapon passing over your sovereign space, you would declare it an act of war and shoot it down. In this day and age many nations have just such capability, and those who don't are usually friendly with a nation that does have the capability, so isn't deploying such a system in itself an act of war? Am I being old-fashioned?

The book, as I said, is very cold, i.e. it displays no emotion but only pure military and technological considerations. I suspect the authors are rather proud of this fact. But for readers (like me) who believe that we must do all we can do to prevent the spread of weapons into space, this book is hard medicine to take. In fact, as I read more and more of the book, the deployment of space weapons seemed more and more inevitable and I found myself getting more and more sick.

But perhaps my illness about weapons in space is a result of wrong thinking, conditioned by long decades of reading articles, books, and reports on the use of nuclear weapons while seeing the US acquire tens of thousands of nuclear weapons for everything from depth bombs, torpedoes and artillery shells to intercontinental missiles. Perhaps if we hadn't thought quite so much--made the use of nuclear weapons seem so inevitable, ordinary, comfortable, advantageous, and necessary--we wouldn't have acquired so many.

In sum, leaving my diatribe aside, this book is recommended to those wishing to be informed about space weapons. I am not aware of any other book that is as comprehensive. Whether you are for or against space weapons this book provides the material upon which to base your arguments. If you are interested in the military use of space or in national security policy, this is a book for you.

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"**Inviting Disaster - Lessons from the Edge of Technology: An Inside Look at Catastrophes and Why they Happen"** by James R. Chiles, HarperBusiness, 2001 (hard-cover $28.00, paperback $19.00 at www.amazon.com)

Since I have worked on problems involving risk assessment and management (RA/RM) for engineered systems, and even testified in Congress on good vs. bad applications thereof, I was very eager to review this book. In anticipation of receiving my review copy from Art Hobson, our P&S book editor, I read the glowing editorial and readers' reviews posted at amazon.com. Sadly, as I struggled to read the book, my high expectations were dashed. From the retelling and forensic analysis of over 50 cited natural or man-made "disasters, calamities and near misses" spanning the last 200 years, I found it very difficult to identify and distill any clear "lessons learned" for preventing and mitigating future occurrences.

Famous accidents are discussed in detail, reflecting quite a bit of research and an honest effort by the author to understand their root causes and to uncover the underlying mechanical or human factors involved. They include: the Thresher submarine sinking, Apollo 1 and 13 fires, the Challenger space shuttle explosion, Bhopal, the Chernobyl and Three Mile Island nuclear reactor accidents, the Hubble Telescope's distorted mirror and the Concorde blowup. There is a lot of good source bibliographic material and some strong human stories in the book, and even some heroes who stand out (like Admiral Rickover, and cool aircraft and pilots). However, I found chapters and sections to be mostly scattered and disorganized, jumping around among events, times, and types of systems. Each chapter is a mish-mash of accidents and ideas, although its title indicates that it was intended to focus on a single theme: the dangers of insufficient testing and how destructive testing can verify design safety; how emergency preparedness planning serves as antidote to failure; what are the limitations of humans in the loop; how lack of foresight or of understanding all possible failure modes can prevent proper system design and operation, etc.

There is no disciplined chronological progression, nor any coherent analysis of inherent risk and safety margins that could be provided in design, construction, test, operation, and maintenance phases for increasingly complex technological systems, operated by fallible humans. No simple and basic lessons are spelled out in this disjointed discussion of selected disasters about how we can successfully design and manage engineered systems of increasing technological complexity and interdependencies. No evidence is presented that the scientists, engineers, and trained technical system operators have actually learned and transferred to practice any valuable lessons from the analysis of famous failures.

A chapter dedicated to the discipline and tools of risk assessment and management, illustrated by both notable failures and successes, would have been quite valuable in educating lay readers. Few of the common RA/RM concepts (such as the probability of occurrences, statistical testing, preventive maintenance, risk profile, safe designs, construction, and fail-safe operation practices) are either explained or illustrated in the book, so as to teach about key concepts. I looked in vain for evidence or mention of key steps in any disciplined failure analysis: hazard identification, absolute or relative risk ranking, single point failures, common-cause failures, and failure chains, event tree and criticality analysis. Similarly, I tried in vain to find examples of successful consequence mitigation strategies for any foreseen engineered system failure, such as redundancy, overdesign, endurance testing and training programs.

By the end of the book, I was quite fatigued by the jumping around from ancient to new accidents, and among the many and diverse types of engineered systems such as cars, planes, ships, boats, helicopters and spacecraft, chemical and propellant factories, offshore oil platforms, etc. Although the book has a good list of resources and a well-organized index, its disaster stories could be both informative and amusing, and its sensationalist style could be entertaining for some lay readers, I cannot in good conscience recommend it to scientists or engineers

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Disciplined Minds, *by Jeff Schmidt*
PUBLISHERS: Rowman and Littlefield, ISBN: 0847693643, $26.95, HARDCOVER

The title, like the book, represents the double-edged sword of professional training. Does one's mind become more disciplined in graduate school—more focused, more devoted to one's subfield? Or is the mind of a graduate student disciplined into obeying the structure and hierarchy unique to one's field of study? In his book, author Jeff Schmidt explores the development of a professional and highlights those factors which he believes perpetuate the insular nature of the professional world.

The book begins with the development and behavior of a professional. Schmidt argues that a basic distinction must be made between a professional and a non-professional: the use of political skills (p.41). A professional, by his definition, is a person that an institution entrusts to maintain the ideologies of that institution. They have been trained to perpetuate the image of the institution.

This kind of professionalism comes at a price. In order to perpetuate the institution's ideologies, the human mind has two options: to genuinely believe in those ideologies-on the clock and off, or only to believe in them when the clock is ticking. Most people do not enter an institution in full agreement with every aspect of that institution's ideologies, so there is some break-in period for novitiates. Schmidt talks about this in the context of graduate school as a "boot camp," where ideals are homogenized into the broth of the institutional soup.

That is, there is an inherent sacrifice of one's own role in the creative progress of the professional field while one is a drone. The example that he describes in much detail is the plight of the graduate student, who must sacrifice time, energy and income for the sake of the doctoral degree. Schmidt believes that the sacrificial nature of graduate school is necessary in order to prepare the student for the transition into a hierarchical system.

Drawing upon his personal experience as a physics graduate student at University of California-Irvine and stories of other students, Jeff Schmidt's book is an exploration into the developmental stages of a young professional. It is, at times, hard to read his book without sensing his bitterness towards his graduate school days leaking through. Perhaps it is necessary for us to be exposed to this bitterness in order to understand the effects that such clashes with bureaucracy can have on an individual.

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2987 words

“WEAPONIZATION” VS. “MILITARIZATION” OF SPACE

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Space as a Sanctuary

Currently, space is not weaponized. There are no weapons deployed in space or terrestrially (in air, sea, or on the ground) meant to attack space objects, such as satellites; nor are satellite weapons deployed against terrestrial targets. At the same time, space is an increasingly vital part of our military activities from which the US obtains great advantages with respect to other nations. We use space for communication; for surveillance and targeting over the battlefields; for weather prediction; for precise mapping and positioning of our own and opposition military assets; for early warning of missile and air attacks; and for general military, economic, and technological intelligence worldwide. Thus space is “militarized” though not yet “weaponized.”

Civil society also makes great use of space – for communications (internet, radio, telephone, TV), navigation, search and rescue, weather, resource and environmental mapping, astronomical and terrestrial research. Because of the great technological and economic strengths of our society, our civil society – like our military – gains relatively greater benefits from our use of space than do our competitors.

Thus *space is a de facto sanctuary* – a region in which we further our competitions, military and otherwise, with other nations, but without actually fighting. In both war and peace, US satellites vitally aid our military – and our civil society – in inflicting and avoiding damage without being under threat themselves. Other nations acquiesce to this sanctuary because they also benefit from it (thought not as much as we).

With some exceptions (e.g., the Reagan presidency), treating space as a sanctuary has been the policy of all US administrations from Eisenhower to Clinton. All other nations have concurred, and still do. For example, both China and Russia have recently introduced space sanctuary UN resolutions backed by over 100 nations. The US has become one of the very few opponents of such multilateral diplomatic activity. In fact, the present administration is pushing hard for the opposite, for the weaponization of space:

“America’s interests in space are to: Develop and deploy the means to deter and defend against hostile acts directed at U.S. space assets and against the uses of space hostile to U.S. interests . . . weapons systems that operate in space . . . Power projection in, from, and through space.” (Commission to Assess United States National Security Space Management and Organization [The “Rumsfeld Commission”], Executive Summary, 1/11/01, pp. 15, 16.)

What’s Up There Now? What Could Threaten It?

Since the beginning of the “space age”, roughly 5400 man-made objects have been placed in orbit around the earth, 1500 of them by the U.S., 3100 by the S.U. and its descendents. Some 580 of these satellites are believed to be still functioning as they were intended. The military have 87 of their own satellites, as well as full access to the remaining civil and mixed-use satellites.

About 270 of these functioning satellites are in LEO **-** "Low Earth Orbits". This region extends from the "top" of the earth's atmosphere (below which satellites would burn-up too quickly due to atmospheric drag) to the bottom of the Van Allen belts (where radiation damage may shorten satellite lifetimes), from about 100 kilometers altitude to about 1000 km. At present this region contains at least 24 U.S. military reconnaissance, electronic intelligence, and meteorological satellites – such as the Navy's GFO 1, NRO's Lacrosse and E-300 series, and the Air Forces DMSP set. France, Israel, and Russia have similar military satellites in this region, which the Russians also use for tactical military communication and navigation. In the future, the U.S. plans to place the "SBIRS Low" (Space Based Infrared System Low) network of two dozen infrared missile-tracking satellites for "TMD" and "NMD" (Theater Missile Defense and National Missile Defense) in this region. (Severe delays and cost overruns have cast doubts on these plans.)

Also in LEO are to be found some U.S. commercial systems such as: Globalstar's 48 satellites providing mobile communications (e.g., real time voice, data, fax) and telecommunications; Orbcom's 35 mobile communications satellites (e.g., providing owners the GPS determined locations of their cargo trucks or oil pipeline monitoring data). Commercial remote sensing, environmental and Earth resources monitoring is provided by U.S. companies. Earthwatch, Inc. provides one meter resolution optical images. Orbimage supplies 1-m optical images plus multispectral images of the land and sea; Space Imaging sells synthetic aperture radar as well as optical images for: agriculture; environmental and mineral resource exploration, monitoring, and planning; forestry; ocean monitoring; ice reconnaissance; mapping media; mining facilities management; oil and gas route and corridor planning; urban and land use planning; and disaster management. Similar services can be purchased from the French firm Spot, from Russia, and from others. China and the U.S. operate weather satellites in LEO. Also important for civilians are search and rescue satellites (such as the Russian Gonets), as well as those used for scientific imaging of the earth's atmosphere, land and sea surfaces: passively via infrared and visible light; actively via radar. The 500-ton, habitable, International Space Station is currently being constructed in LEO

It is this LEO region, closest to earth, which will be most vulnerable in the near future to earth-based **ASATs**, "Anti-Satellite" weapons (missiles, lasers,particle beams, etc.), currently under development by several states. For example, the American MIRACL laser has damaged orbiting satellites, as have Russian lasers. The mid-course missile interceptor currently being developed for the U.S. NMD program will be able to target satellites up to altitudes of at least 1200 kilometers. There are many countries possessing IRBMs, missiles having ranges of 3500 km or more; they will be able to reach up to all satellites in LEO. Iraq's al Hussein, a modified Scud-B, could climb to 300 km, enabling it to reach Russia's Cosmos 2370, a military satellite imaging Chehnya. The technical prowess required for great accuracy would not be necessary to harm the targeted satellite: a simple nuclear explosion, or the dispersal of a cloud of pebbles, would suffice to damage all satellites in a large region of LEO for an extended period of time. There is also research underway in the U.S on space-based ASATs – both missiles (e.g., "Brilliant Pebbles" – orbiting, self-guided, self-propelled) and lasers (SBL).

There are some 40 to 50 satellites in MEO, **"**Middle Earth Orbits", orbiting at altitudes between 1000 and 35786 kilometers above the surface of the earth. Presently in this region are science satellites (e.g., the U.S. Chandra and GGS Polar, Japan's Halca and Nozomi, Europe's XMM), and navigation satellites (used for personal, commercial, and military transportation as well as for military targeting). The U.S. military/civilian NAVSTAR **G**lobal **P**ositioning **S**ystem embodies 29 of these satellites whereas the Russian Cosmos, Glonass, and Parus series totals 19 navigation satellites; some of these are non-operating spares. Also in this region are some Russian early warning satellites (Cosmos 2361 and the Oko sat). Most of these MEO satellites are in highly elliptical orbits, dipping into the LEO region during part of their travels. During these close approaches to earth, they would have the same vulnerability as do the LEO satellites.

Finally, there are about 300 satellites in GEO**,** "Geostationary Earth Orbits". These circulate easterly, precisely 35786 kilometers above the Equator with a period of 24 hours; hence they remain stationary with respect to any given position on the surface of the earth. At least 29 of these belong to the U.S. military. Other militaries owning satellites in this region are Australia, Russia, and Britain. These stationary satellites serve for communications, relay, earth observation, search and rescue, weather, and research. There are also constantly staring "early-warning-satellites" (such as the U.S. DSP, and the planned SBIRS High, and the Russian Prognos), designed to detect (and initially track) ballistic missile launchings via the intense infrared emitted by their rocket engines. Some examples of U.S. commercial systems in this region are: DIRECTV, Inc. selling direct-to-home TV broadcasting; Echostar, offering business services; GE American Communications, providing broadcasting, telecommunications, cable programming, business services, direct-to-home TV broadcasting, internet access. Intelsat, Lockheed Martin Global Telecommunications, Loral Skynet, Motient Corp., PanAmSat Corp., and WorldSpace Corp sell similar services. Non-American firms selling such services are based in Japan, Germany, Brazil, France, Spain, UK, Korea, Philippines, Argentina, Netherlands, Indonesia, China, Luxembourg, Israel, Norway, Canada, and Turkey.

For the foreseeable future, the only threats to such "far-out" satellites would come either from other such satellites (firing lasers or missiles such as "Brilliant Pebbles") or from the rockets capable of launching such satellites from ground to GEO (releasing conventional or nuclear space mines or gravel clouds). At present only China, France, India, Japan, Russia, Ukraine, and the U.S. possess such rocketry.

Space Sanctuary or Space War?

It should be abundantly clear by now that U.S. civil life and prosperity is bound up with the smooth functioning and predictability of commercial satellite systems (ground and launching stations, satellites, command and control communication links), internationally and American owned and operated. Also increasingly evident (e.g., Gulf War, Balkan Wars, Afghanistan) is the dependence of the U.S. military, and the resultant discomfort of its opponents, upon space systems– its own, and civil ones. For example, many of the aerial munitions used in Afghanistan were guided to their targets by GPS. America's opponents in any future conflict would like to obstruct its use of space. Hence the U.S. would like to protect its space assets while simultaneously hindering access to space by its opponents.

One possible U.S. policy is the development and deployment of *active* defense and offense in space – the ability to conduct war in space. Terrestrial and satellite based

ASATs would be intended to target enemy ASATs as well as the opponent's militarily relevant satellites. If the opponents are not technologically advanced nations (or non-national groups), they will not have their own space assets – just rely upon commercial space systems. Then the U.S. would have no space targets against which to deploy unless it wished to threaten civil space assets. It would then be creating a space-arms-race against itself as well as hindering the development of space commerce – insurance and investment capital does not freely flow to war zones. Such a policy would also antagonize other nations – technically backward or advanced, perhaps creating opponents where none previously existed; no one likes a hegemon. If, on the other hand, the opponent is technologically able to wage war in space (Europe, Russia, China, India, ?), they may respond to a U.S. run in space by competing. In addition to harming civil space commerce, such an expensive race would obstruct the U.S.'s present free ability to use space in furtherance of its terrestrial military objectives. Opponents in such a race would be able to threaten the U.S. with nuclear weapon carrying ICBMs while also endangering its early warning satellites. We would be returned to the terror of the Cold War - without its stabilizing contribution of certain knowledge of the opponent's pre-attack actions.

The alternative is *passive* defense of space assets together with a treaty guaranteeing a space sanctuary (= no weaponization of space). Though an overwhelming majority of nations in the UN (including all of the technologically adept ones, except the U.S.) have expressed support for a treaty Preventing an Arms Race in Outer Space (PAROS), such a treaty by itself would not be sufficient. There would always be fear of surreptitious weaponization of space by the opponent. (Verification would be difficult; it's hard to determine whether what's inside another's satellite is a forbidden weapon.) Passive defense of satellites would include miniaturization, redundancy, quick re-launch capability, shielding, coding and localization of communications links, and the development of alternative means to achieve current space tasks (e.g., high-altitude drone aircraft for communication and observation). Such an approach would also be expensive – but it would further, not hinder, the development of space industry. It would also further, not hinder, international stability.

In as much as an emphasis on commerce, rather than military, has always seemed to be a preferable approach to peaceful and prosperous relations among states in the international system, it would seem that the PAROS approach to space should be the preferable one. At present, the alternative approach, weaponizing space, seems to be preferred by the American administration.

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The Status of Women in Physics – An International Meeting on What, Why, and How to Change

Meg Urry

I. Too Few Women in Physics

The number of women in physics is low, in the U.S. and globally, and has been increasing only very slowly. The dearth of women in physics is an urgent concern. The best physics demands the best brains from more than just half of humanity; excluding women weakens physics and all of science. Just as important, women deserve the same opportunity as men to have a stimulating and rewarding career in physics. Also, a more scientifically literate public, one that includes girls and women educated in physics, will lead to more public support of science.

II. Organization and Event Details

On March 7-9, 2002, the International Union of Pure and Applied Physics (IUPAP) held an International Conference on Women in Physics at the UNESCO headquarters in Paris, France. This meeting, the first of its kind, was organized with two major purposes in mind:

(1) to understand the severe under-representation of women in physics and related fields worldwide, and

(2) to develop and implement strategies to increase the participation and representation of women in physics.

A large number of international institutes and organizations sponsored the meeting, including major U.S. federal funding agencies, the American Physical Society and U.S. national laboratories. These organizations united in recognition of the fact that an understanding of the status of women in physics will likely provide insights and approaches that could be applied to other fields and professions where women are inadequately represented.

The conference was motivated by the fact that the global scientific work force is under-utilizing a large percentage of the available talent pool. Although the situation differs widely from country to country, there is a remarkable consistency in one sobering pattern: the percentage of women in physics decreases markedly with each step up the academic ladder or with each level of promotion in industrial and government laboratories. The presence of women physicists in the upper echelons is critical for the health and diversity of the field. Since a number of physics faculty positions should be coming open as faculty hired in the sixties and seventies retire, it was especially timely and important to have an international forum to address the under-representation of women in physics.

More than 350 participants in delegations from 65 countries attended the conference. The delegates came from academic institutions, national laboratories, industry, and other sectors. The U.S. delegation was sponsored by the American Physical Society and selected by the CSWP (the APS Committee on the Status of Women in Physics). Its 12physicists represented a diversity of backgrounds and expertise and had expressed a firm commitment to following up on recommendations that emerged from the conference.

This U.S. delegation's report on the IUPAP meeting serves as a means to restart a national dialogue about the status of women in physics in the U.S.

The format of the IUPAP conference included significant input and feedback from the participants, who brought an enormous diversity of backgrounds and issues to be addressed at the meeting. As an introduction to the status of women in their countries, each delegation submitted a 2-page contribution for the proceedings, as well as a poster on the topics concerning women in physics in their country. The conference itself included plenary sessions with invited speakers and small group discussions on six specific topics

: 1) Attracting Girls into Physics,
2) Launching a Successful Physics Career,
3) Getting Women into the Physics Leadership Structure Nationally and Internationally,
4) Improving the Institutional Climate for Women in Physics,
5) Learning from Regional Differences, and
6) Balancing Family and Career.

The discussion groups generated many ideas for improving the status and representation of women in physics. These were distilled into a set of resolutions ratified by the conference, plus an additional set of more detailed recommendations for use in participants' home countries as appropriate. Specific resolutions were directed at individuals, schools, universities, research institutes, industrial laboratories, scientific and professional societies, national governments, granting agencies, and the IUPAP itself. These consensus guidelines will be used by individual delegations to stimulate change in their own countries, with the exact language modified according to the culture and conditions of each country.

The resolutions and recommendations represent a portion of the key results from the IUPAP conference. IUPAP also plans to provide extensive on line resources related to women in physics, including the materials from the conference, a database of women physicists worldwide, opportunities for global exchange and collaboration, and links to international organizations for women in physics and science, as well as to other international institutes and conferences on related topics. (Further information may be found at http://www.if.ufrgs.br/~barbosa/conference.html).

III. Findings, Results, and Highlights

Prior to the conference, the IUPAP Working Group on Women in Physics, in collaboration with the Statistical Research Center of the American Institute of Physics, undertook an international benchmark study on women in physics. They collected demographic information from more than 800 women in 50 countries. The data included individual experiences and concerns as well as education and employment histories. Results were presented at the conference and are available online (Ivie, Czujko, and Stowe, http://www.aip.org/statistics).

Two-thirds of the women surveyed had Ph.D. or higher degrees. Three out of four respondents said that they would choose the path of physics again, although the same fraction of women felt the situation for women physicists in their country must be improved. By its very nature, the survey did not include women who left physics, or those who never pursued it. Thus, it is worth noting, we do not have data concerning the very women who must be brought into and/or retained in the profession if the numbers are to change significantly.

The statistics show that women around the world face similar barriers to their success in physics. Even in countries where it is as common for girls to study physics as for boys, the number of women physicists drops sharply with advancing level. At the top of the profession --- meaning senior faculty and directors of research institutions --- women are typically only a few percent or less of the total. To a large extent, the absence of women from physics is an invisible problem; it is not commonly discussed in the international physics community, and few resources are devoted to improving the situation.

The large variations from country to country, and in particular, the 50/50mix of young men and women at the undergraduate level in many countries, indicate that there are no intrinsic intellectual barriers to women's participation in physics. Rather, the barriers must somehow be cultural, i.e., related to societal norms and educational practices in the individual countries.

The conference identified some critical factors leading to the low representation of women in physics throughout the world. First, societal and individual family pressures often dissuade women from becoming or staying involved in physics careers. Both the survey data and the conference discussions made clear that support from women's families, husbands, teachers, advisors, and colleagues is crucial in attracting women to physics and keeping them in the field. Second, the long apprenticeship period in some countries encourages the disproportionate attrition of women in going from undergraduate and graduate studies to permanent positions in their sub-fields of physics. In particular, the "post-postdoc" phase appears to be the most leaky stage of the pipeline, regardless of the greatly differing representation of women in the various countries. Many delegates speculated that this was because of the overlap of the early-career years with the peak marriage/childbearing years, and because of the requirements for frequent relocation and travel.

Third, two serious concerns for women in physics across almost all nations were the dual career or trailing spouse problem (because most women physicists are married to other physicists or scientists), and balancing career and family. These issues tend to affect women's careers far more than men's, with women physicists reporting broken or commuting marriages, and deferred or no childbearing. (From the AIP report, two-fifths of respondents had no children, with one-fifth of those older than 45 years having had no children.) Many conference participants emphasized the importance of choosing one's spouse to ensure mutual understanding and support of each other's careers, and equal participation in family duties.

It is worth noting, however, that family issues cannot be the major barrier to success for women already in physics. For one thing, women without children do not appear have more success in physics than do women with children. For another, countries with strong family support systems(daycare and maternity leave), like some Scandinavian countries, have in fact one of the lowest representations of women physicists. Finally, women are present in higher numbers in biology, medicine, chemistry, mathematics and other very demanding professions --- there is nothing specific to physics about the conflict between work and family. Still, at least one study has showed that men in physics with children tend to have more influential and well-paid jobs than men with no children, whereas the exact opposite is true for women physicists, showing that male physicists are directly rewarded for factors that their female counterparts are penalized for.

Fourth, women have little exposure to physics early in life; many societies believe that physics is not for "normal" people, much less for women. In addition, there is a general lack of appreciation of the usefulness of physics and a lack of awareness of the excellent job prospects for physicists and specifically for women. These issues, complicated by the fact that young women lack role models and female peer groups in physics, lower the numbers of women in physics in very early stages of education and begin to explain why physics has so many fewer women than sciences with similarly demanding lifestyles, such as biology or medicine.

Fifth, nepotism (the support of one's own students) and "cloning" (the selection and nurturing of students who resemble the professor) lead to the exclusion of women in male-dominated environments, of which physics is one of the most extreme examples.

Sixth, the lack of transparency in recruitment and hiring processes tends to work against women. Shifting or poorly articulated standards for hiring and promotion lead to uneven reviews, which are particularly detrimental to those without strong advocates within the system. These inequities can also serve as a deterrent, making science far less attractive for women.

Seventh, sexual harassment and overt discrimination strongly discouragewomen from pursuing physics and related fields. While perhaps rare, suchan event is devastating when it occurs.

Together these issues begin to explain the dramatic under-representation of women in physics relative to other scientific fields. At the IUPAP conference, much attention was paid to concerns about balancing career and family, including childbearing and the two-body problem, but it was also noted that these issues are common to women pursuing any demanding career. So why are women better represented in other scientific and technical fields than in physics? A closer examination of those factors that are particular to physics must be undertaken. Both the structure of physics education and the "chilly climate" for women in physics may be contributing factors, and indeed may be coupled. Simply increasing the number of women in the physics educational pipeline will not improve the professional situation if women continue to leave the field at a high rate at each juncture in their careers.

When women are represented at all levels of the decision making, many of these issues are effectively addressed, a point made decisively by U.S. professor of biology Nancy Hopkins about her institution, the Massachusetts Institute of Technology. Sustained cultural change occurs when women are fully integrated at all levels in an institution. This appeared to be the case in France, for example, where representation of women is much better than in the U.S., and where the presence of women in leadership roles is seen as commonplace. When women are marginalized and when a culture is not under pressure to change, the aggressive, competitive, non-collaborative atmosphere that some call "combat physics" can prevail.

IV. Across Many Nations

The IUPAP conference revealed regional differences arising from social, cultural, and economic considerations. Although there were no clear pan-national solutions, an ambitious first step in that direction was the identification of common deterrent factors, as well as of the differing needs of women physicists around the world. For example, marriage and childbirth occurred far earlier in developing relative to developed countries. From the AIP report, about one-third (one-fifth) of women physicists in developed (developing) countries are not married, with about 38 percent (60 percent) of marriages occurring during their education. There were also significant differences in the timing of having children. The percentage of women physicists in developed (developing) nations who made the decision to have their first child in school, after their final degree, or to have no children was respectively 13, 34, and 53 percent (40, 32, and 28 percent).

There were some socio-statistical surprises. Scandinavian countries, whose employment systems reduce some of the family-related barriers to women, nevertheless have some of the lowest female physics Ph.D. rates. Several countries stand out as having large undergraduate enrollments in physics, notably India, Iran, and Italy. In India there are roughly equal numbers of men and women physics students through the Master of Science level. Iran had the highest percentage of female college-level enrollment in physics, whereas Sweden was almost last in the world. In several developing nations, women were free to use their maiden name on their publications but, perhaps surprisingly, in a well-developed country like Belgium, women physicists are required to use their husband's last name on their publications. It was also found that developing nations often led developed ones in providing flexible working hours and state support for couples trying to balance the needs of family and career.

V. Recommendations

A primary focus of the conference was to articulate ways to create a better future for women in physics --- a future in which the physics culture is more inclusive of difference, whether it be gender, race, or class. Some proposed steps to achieve this future are listed here. (These are meant as possibilities rather than a complete set of recommendations, and they are not expected to be applicable in all situations.)

1) Recognize the positive benefits of a diversity of perspectives to physics as a discipline.

2) Include women in the power structure, to help make the decisions that shape the field.

3) Ensure that key decision-making processes are transparent -- i.e., policies are well-known and outcomes are clearly reported. Key decisions include those related to hiring, salary, promotion, resource allocation, peer review, and speaker selection.

4) Work for the positive portrayal of physics and physicists. Increase the visibility of women physicists in the media and press, and in the next generation of physics textbooks.

5) Ensure a grant system and academic path that do not discriminate against women. In regions or sub-fields where the numbers of women are particularly low, institute special incentive scholarships for girls and awards or prizes for women.

6) Abolish a source of age discrimination by using academic age (years since Ph.D.) rather than biological age in competitions for prizes, positions, and grants/fellowships.

7) Recruit more women into national and international collaborations.

8) Emphasize the value of doing physics early in science education. Improve physics teaching, and provide talented enthusiastic physics teachers for schools.

9) Encourage interaction between universities/labs and schools.

10) Provide mentoring programs for young girls in physics. Counsel parents, teachers, and career counselors to encourage girls to pursue physics.

11) Establish flexible career paths from the Ph.D. through the tenure phase in order to integrate the demands of family and career more easily. Provide an option to stop the career clock while women (or men) are preoccupied with family. Organize flexible grant structures that can adjust to non-traditional career paths. Possibly offer permanent positions earlier to women.

12) Provide convenient and affordable day care. Make work-related travel easier during the years when children are young.

V. Conference Outcome

In addition to the highly informative and eye-opening aspects of the conference, the IUPAP delegates shared a sense of excitement and solidarity, generated by the presence of so many outstanding women physicists. Many delegates, men and women both, described how empowering it was to have an international forum in which to discuss the integration of their love for doing physics with their values and goals as human beings and as members of society. Despite the fact that most of the women had overcome severe obstacles in order to reach their present positions, they communicated a sense of hope and a positive vision of the future, with a shared message of "Let us do physics: as women!"

See http://www.if.ufrgs.br/~barbosa/conference.html
A summary of the IUPAP conference may be found in the May 2002 APS News

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ARTICLES

DOES THE U.S. NEED NEW NUCLEAR WEAPONS?

Frank N. von Hippel,

For the past decade, the public has treated the danger from nuclear weapons as if it ended with the end of the Cold War. Never mind that the U.S. and Russia each still keep 2000 missile warheads ready to launch at each other within 15 minutes. To the extent that nuclear weapons appear in the news at all, it is via the concern that terrorists might acquire them.

In the meantime, the three U.S. nuclear-weapon laboratories, Los Alamos, Sandia and Livermore, are getting more money for nuclear-weapon R&D than ever. This money is for the "Science-based Stockpile Stewardship Program," whose purpose is to assure that the nuclear warheads in the U.S. arsenal remain reliable (which means a yield close to the design yield) and that the U.S. retains its ability to design new nuclear warheads.[1] As a substitute for nuclear tests, the weapons labs have demanded costly installations with which to simulate and replicate on a small scale the physical conditions inside a nuclear explosion. These installations include ever-more-powerful supercomputers and the multi-billion dollar National Ignition Facility.[2]

The leaders of the laboratories have also been agitating for permission to develop new types of nuclear weapons to meet the challenges of the post-Cold War era. During 2000-2001, the senior weapons scientists of Los Alamos and Sandia both issued "white papers" calling for a new family of low-yield precision-guided nuclear weapons to enable the U.S. to make credible threats to attack key facilities in threatening states. The first lab white paper, *Nuclear Weapons in the Twenty-first Century,* was by Stephen M. Younger, who was Los Alamos Associate Laboratory Director for Nuclear Weapons in June 2000 when the paper was published.[3] The second, *Pursuing a New Nuclear Weapons Policy for the 21st Century*, was put out in March 2001 by C. Paul Robinson, Director of Sandia National Laboratories. Judging from the recently leaked report of the *Nuclear Posture Review,* the labs seem to have found a sympathetic audience in the leadership of the new Bush Administration's Department of Defense.

Younger: Reintroduce HEU gun-type designs

Younger argued for a new class of nuclear weapons that would offer both "arms control advantages to the United States, and the possibility that such weapons could be maintained with higher confidence and at lower cost than our current nuclear arsenal."

This class turns out to be the "gun-type design" that was used in the Hiroshima bomb, which had a yield of about 15 kilotons TNT equivalent. This design involves one subcritical piece of highly-enriched uranium (HEU) being propelled into another to make a supercritical

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[1] The Bush Administration budget request for stockpile stewardship in fiscal year 2003 is $4.6 billion.

[2] Most of the money is, in fact, dedicated to maintaining U.S. nuclear-weapon design capabilities in the absence of testing. Robert Civiak, a physicist who was, during 1988-99, the official in the Office of Management and Budget responsible for reviewing the Department of Energy's nuclear-weapons budget, outlines different possible approaches to stockpile stewardship in *Managing the U.S. Nuclear Weapons Stockpile: A Comparison of 5 Strategies* (Tri-Valley CAREs, July 2000, www.trivalleycares.org/reports.asp). A group of physicists at the Natural Resources Defense Council has produced a series of studies critiquing the stockpile stewardship program and the National Ignition Facility http://www.nrdc.org/nuclear/nif/nifinx.asp.

[3] Younger was subsequently appointed Director of the DoD's Defense Threat Reduction Agency.

mass. Its arms-control advantage is that it "might be maintained with high confidence without nuclear testing." And its cost savings would stem from the fact that HEU is less costly and contaminating to process than plutonium. Younger added, however, that "some very hard targets require high yield to destroy them" and that high-yield weapons with yields of hundreds of kilotons or more would also have to be preserved for "traditional deterrent roles," i.e. the ultimate threat to destroy a country's cities. For such purposes, he indicated, it would be necessary to retain nuclear weapons of current designs. These designs have fusion "boosted" plutonium "pits," which are imploded to achieve supercriticality. The energy of the resulting explosion then ignites thermonuclear reactions in the warhead's "secondary."

Unfortunately, would-be nuclear terrorists are also likely to recognize the simplicity of gun-type designs using HEU. To minimize the likelihood of nuclear terrorism, therefore, the number of locations in the world where HEU can be found should be greatly reduced.[4]

Robinson: More uses for nuclear deterrence

Robinson explained that he felt compelled to write his "white paper" because

> "I recently began to worry that…far too many people…were beginning to believe that perhaps nuclear weapons no longer had value. It seemed to me that it was time for someone to step forward and articulate the other side of these issues for the public: first, that nuclear weapons remain of vital importance to the security of the U.S. and to our allies and friends…and second, that nuclear weapons will likely have an enduring role in preserving the peace and preventing world wars for the foreseeable future."

Robinson then went on to urge that the U.S. maximize the leverage of its nuclear capabilities for "deterring wider acts of aggression from any corner of the world, including deterring the use of nuclear, chemical or biological weapons."

Robinson acknowledged that, as an inducement to non-nuclear-weapon states to remain non-nuclear, the U.S. has repeatedly committed that it will not use nuclear weapons against them unless they attack the U.S., its allies or its military forces in alliance with a nuclear-weapon state. However, he argued that "those who would advocate that we should not be allowed to consider deterring chemical or biological attacks with our nuclear arsenal must first show how such attacks might be deterred by other means."

The Nuclear Posture Review orders up a new nuclear bunker buster

The Department of Defense – perhaps in response to such urgings from the weapons labs -- officially reopened the issue of new nuclear weapons in the December, 2001 report produced by its Nuclear Posture Review (NPR). The report called for the development of an improved earth-penetrating nuclear warhead to make it possible to attack deeply buried bunkers which might shelter infrastructure related to Weapons of Mass Destruction [WMD]:[5]

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[4] Frank von Hippel, "Recommendations for preventing nuclear terrorism," *Federation of American Scientists Public Interest Report,* www.fas.org/faspir/archive.htm.

[5] *Nuclear Posture Review*, classified report submitted to Congress, December 31, 2001, leaked excerpts available on www.globalsecurity.org.

"More than 70 countries now use underground facilities…for military purposes. In June 1998...approximately 1,100 UGFS were known or suspected strategic (WMD, ballistic missile basing, leadership or top echelon command and control) sites. Updated estimates from DIA [Defense Intelligence Agency] reveal this number has now grown to over 1,400…current conventional weapons are not effective for the long term physical destruction of deep, underground facilities…

"With a more effective earth penetrator, many buried targets could be attacked using a weapon with a much lower yield than would be required with a surface burst weapon. This lower yield would achieve the same damage while producing less fallout (by a factor of ten to twenty) than would the much larger yield surface burst. For defeat of very deep or larger underground facilities, penetrating weapons with large yields would be needed to collapse the facility…"

When are nuclear weapons useable?

The proposed new nuclear bunker buster has raised again the perennial question of whether nuclear weapons are useable except as a last resort to deter threats to the existence of the U.S. If not, what do we need new types of nuclear weapons for?

The U.S. has made nuclear threats in the past in connection with confrontations that did not threaten the existence of the nation. During the Korean War, both Presidents Truman and Eisenhower threatened to use nuclear weapons in an effort to force an armistice on China and North Korea. President Eisenhower later threatened to use nuclear weapons to stop Chinese artillery bombardment of the Taiwan-controlled offshore islands of Quemoy and Matsu. President Nixon similarly made barely veiled nuclear threats in his effort to obtain a face-saving end to the Vietnamese War. In the end, all three presidents realized, however, that the domestic and international political costs of breaking the nuclear taboo that had built up since 1945 vastly outweighed the military benefits from nuclear-weapon use.[6]

The view that nuclear weapons are not useable in ordinary warfare is shared by the general public, which believes that we have nuclear weapons only to deter the use of nuclear weapons by others against us.

The U.S. nuclear-weapons establishment argues, however, that nuclear weapons should be available as well not only to deter but also to preempt attacks with other so-called weapons of mass destruction, such as chemical or biological weapons. Indeed, a deep bunker filled with containers of chemical or biological agent has become the poster child used to justify the development of a better nuclear bunker buster.

The potential consequences of a chemical-weapon attack – although horrible – would not be in the same class as nuclear weapons. The worst-case toll from a biological weapons attack could potentially be comparable to that from a nuclear attack.[7] But such an attack, if not by a terrorist group, would likely be from a country that the U.S. could easily defeat and occupy with conventional forces. And, if the U.S. can seize the area over a WMD bunker, it does not need a nuclear weapon to destroy it.

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[6] See the relevant sections of McGeorge Bundy, *Danger and Survival: Choices about the bomb in the first fifty years* (Random House, 1988).

[7] *Proliferation of weapons of mass destruction: Assessing the risks* (Congressional Office of Technology Assessment, 1993, www.princeton.edu/~ota) pp. 53-54.

Thus the Pentagon's proposal for a new nuclear bunker buster has raised again the issue of the usability of nuclear weapons for more than deterring nuclear attack. In May, the Senate Armed Services Committee voted 13 to 12 not to provide the $15.5 million requested for the development of a new nuclear earth penetrator. This was just the first round of what is likely to be a sustained debate.

Resumed nuclear testing?

A closely related front in this new debate is likely to be over nuclear testing. The NPR report warned that:

> "The United States has not conducted nuclear tests since 1992 and supports the continued observance of the testing moratorium. While the United States is making every effort to maintain the stockpile without additional nuclear testing, this may not be possible for the indefinite future. Some problems in the stockpile due to aging and manufacturing defects have already been identified. Increasingly, objective judgments about capability in a non-testing environment will become far more difficult. Each year the DoD and DOE will reassess the need to resume nuclear testing and will make recommendations to the President. Nuclear nations have a responsibility to assure the safety and reliability of their own nuclear weapons."

In addition, the NPR states that the need for new nuclear warheads may require testing the new designs:

> "To further assess … nuclear weapons options in connection with meeting new or emerging military requirements, the NNSA [the National Nuclear Security Administration, which has responsibility for nuclear-weapons within the Department of Energy] will reestablish advanced warhead concepts teams at each of the national laboratories and at headquarters in Washington…DoD and NNSA will also jointly review potential programs to provide nuclear capabilities, and identify opportunities for further study, including assessments of whether nuclear testing would be required to field such warheads."

Here -- as throughout the NPR report -- its authors seem oblivious of the potential reactions of other countries to the proposed policy. Among the threatening messages that are conveyed by a nuclear-testing program are that "the nuclear weapons we have work and we are developing new more useable varieties." Such a message could only encourage other countries also to think of nuclear weapons as useable. That is certainly not in the interest of the United States.

Activist physicists needed

In the likely forthcoming national debates over new nuclear weapons and renewed nuclear testing, concerned physicists must once again become active and help educate the public about the continuing nuclear danger and about measures that could reduce it.

It has been almost two decades since we have had a national debate over nuclear weapons and most members of the general public have either never learned or forgotten the basics. There are also opportunities to use your physics in new ways. A recent analysis by a young astrophysicist, for example, showed that it is physically impossible for a kinetic earth penetrator to reach depths great enough to contain the radioactivity from a weapon with a yield as low as 0.1 kilotons.[8] This analysis was heavily cited in the recent Congressional debate over funding for the development of a new nuclear bunker buster.

George Kistiakowski, who developed the implosion system for the first plutonium bombs and later became President Eisenhower's science advisor, ended up believing that the most effective way to change weapons policy was from the outside. Just before he died in 1982, he made the following statement in the *Bulletin of Atomic Scientists*:

> "As one who has tried to change these trends, working both through official channels and for the last dozen years from the outside, I tell you as my parting words: Forget the channels…Concentrate instead on organizing…"

My own experiences as an insider and outsider have led me to the same conclusion.

The debate will have to be driven by activists of all types – not just physicists. Without activists of all types bringing the issues to the attention of the media and the politicians, there won't be an audience for the physicists. But without the physicists joining in to lend their credibility, the other activists are likely to have little impact in affecting policy. As the anti-nuclear activists used to say: "Better active now than radioactive later."

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[8] Robert Nelson, "Low Yield Earth Penetrating Nuclear Weapons," *Federation of American Scientists Public Interest Report,* January/February 2001, p.1, www.fas.org/faspir/archive.htm; and *Science & Global Security* (forthcoming).