COMMENTARY

Gaps in APS Position on Nuclear Energy

Gerald E. Marsh and George S. Stanford

The American Physical Society recently issued a position paper entitled "Nuclear Energy: Present Technology, Safety, and Future Research Directions: A Status Report" (<www.aps.org/public_affairs/popa/reports/nuclear.shtml>). It is an excellent snapshot of the current status and future potential of nuclear energy -- but there are a few matters that should have been more carefully addressed.. As noted in the Preamble, the earlier, 1993 APS position on nuclear energy called for "the development and implementation of programs for the safe disposal of spent fuel and radioactive waste." We have some comments on voids that the current report leaves in those areas, and others.

Economics. In the section subtitled *Advanced LWR Designs*, the report states that "the cost of electricity from these plants has also been improved and is estimated to be lower than today's nuclear plants by about 20%. Yet, the capital cost is still too high to be competitive with gas-fired plants in the U.S. rate deregulated market, assuming present gas prices." Fair enough as stated, but this is a red herring. Gas plants now are used mainly for peaking. If U.S. electric utilities ever turned to gas-fired plants to supply base load on a large scale (which is what advanced LWR designs are all about), the demand for natural gas would balloon, and with it the price of gas-fired electricity and the cost of heating homes.

Safety. In the subsection *Economics and Safety*, the report states that "the safety of operating reactors has been excellent since the TMI and Chernobyl accidents." This is true, but the two accidents should have been distinguished. TMI was scary, and caused some panic, but hurt no one except the pocketbooks of local rate payers. A Chernobyl type accident (a graphite fire) could not happen to civil reactors in the U.S. -- none uses a graphite moderator. This distinction is important.

Reprocessing. The last sentence of the "Security" section maintains unequivocally that "reprocessing separates out plutonium, which is a serious proliferation concern." While this is true for the aqueous "Purex" process that is used to treat thermal-reactor fuel, it is simply not a valid generalization -- a startling blunder by the authors of the APS evaluation.

For one example, it is no secret that pyrometallurgical processing, as developed at Argonne National Laboratory for use with metal-fueled fast reactors, is *incapable* of producing plutonium of the chemical purity needed for weapons. If the starting material is spent oxide fuel from thermal reactors, the initial reduction step also can be done by a process that does not involve separated plutonium.

Indeed, the whole issue of reprocessing should be reexamined by the APS. Perhaps the foremost reason has to do with waste disposal.

Yucca Mountain. The problems associated with waste disposal stem primarily from the notions that spent reactor fuel is waste, and that this waste must be isolated for 10,000 to 20,000 years. Change the assumptions and the problem disappears.

In the light of new technologies, past reasons for not reprocessing spent fuel are no longer convincing. Anyway, the issue is moot, because other nations are already reprocessing their fuel (using Purex). With fast reactors and proliferation-resistant pyroprocessing, the time the actual waste needs to be isolated drops to less than 500 years. Geological disposal for that long is almost trivial.

Appropriate reprocessing, coupled with advanced fast reactors, can extract from the mined uranium over 100 times the energy that is obtained without reprocessing. While this may not be important in the current market with its glut of enriched uranium, that will change. As we understand it, current plans are to keep the spent fuel stored in Yucca Mountain retrievable for 100 years. That is certainly prudent -- our generation has no moral right to deny that rich energy source to future generations. Yucca Mountain should be thought of as an interim spent fuel repository.

As for the safety of the waste, that's another red herring. Already there is far more radioactive waste under the ground at the adjacent Nevada nuclear test site than would ever be expected to leak from the Yucca Mountain repository (even in the absence of recycling). At least four tons of plutonium remains at the test site as bomb residue, along with a much greater quantity of radioactivity due to fission products. The safety of this totally unconfined residue has never become an issue – evidence that concern over the repository is not really about public safety, either now or thousands of years from now.

The debate over Yucca Mountain is really a surrogate for the disagreement between those who see nuclear power as essential to meet the burgeoning energy needs of the world, and those who see it as an evil genie that should be stuffed back into the bottle.

While technological advance will continue, the reassuring outlook for the safety and proliferation-resistance of nuclear power would be more apparent if the implications of even the current state of the art were more widely understood. The APS has been helpful in this regard, and would be even more so if it were to round out its analyses.

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Nuclear Terrorism

Donald D. Cobb

A radiological dispersal device, or RDD, commonly called a "dirty bomb," is a device other than a nuclear explosive device intended to cause damage to the environment and to the public health by dispersing radioactive material.

An improvised nuclear explosive device, or IND, as the name implies, is a device that produces explosive fission energy release (yield). Such devices are called "improvised" to distinguish them from the highly sophisticated nuclear weapons found in the arsenals of the nuclear weapon states. Depending on the sophistication of the developer and access to the requisite nuclear material, highly enriched uranium or plutonium, the yield of an IND could range from a few pounds of TNT equivalent (a "fizzle") to several kilotons.

For four decades the principal nuclear-related threat has been the proliferation of nuclear weapons to countries other than the five nuclear weapon states, as codified in the Nuclear Nonproliferation Treaty (1970). The United States has invested substantial resources for many years in guaranteeing the security of weapon usable nuclear materials and has been a leader in establishing international controls. Nuclear terrorism, while of concern, was generally put in the "too hard" category for international terrorist or sub-national groups. It was thought that the controls on nuclear materials and nuclear weapon technology would be sufficient to discourage terrorists. Since September 11 this assessment has changed. The threat that terrorists might use RDDs or INDs must now be considered more credible. Furthermore, the possibility that terrorists might obtain access to a stolen nuclear weapon cannot be completely ruled out. It is clear that Al Qaida, the Aum Shin Rykyo cult in Japan, and the Chechen rebels all wanted access to nuclear materials or weapons to inflict maximum damage on their targets while causing mass hysteria among the population.

The attack on the World Trade Center released an amount of energy equivalent to about 140 tons of TNT. If this same amount of energy had been released as the result of an IND the Towers would likely have collapsed immediately with even more catastrophic loss of life, and the fallout from such a device, depending on how much radioactive material was lofted into the prevailing winds, could have contaminated much of lower Manhattan and beyond. This contaminated area would have required years and tens of billions of dollars to clean up.

The first line of defense against nuclear terrorism is to deny the terrorists access to the required nuclear materials. The International Atomic Energy Agency (IAEA) definition of **direct use material** (that, is nuclear materials directly usable in a nuclear explosive device) consists of highly enriched uranium (HEU, >20% U235) and plutonium (Pu, <80% Pu238). The IAEA defines **significant quantities** of these materials as 25 kg HEU and 8 kg Pu. While "significant quantities" are not the same as "weapon quantities," they set a threshold for safeguards timely detection of theft or diversion. Clearly, intensive effort is required to control and account for nuclear materials in such small quantities.

Nuclear weapons and weapons-usable nuclear materials tend to be held under tight government oversight. Protection of radiological sources, on the other hand, has more to do with safe use than with security against theft or diversion. Isotopic sources (for example, Cs137, Co60) ranging from much less than one curie to hundreds of curies are in common use for medical and industrial applications. There are no international safeguards or export control regimes for the possession and use of such sources comparable to IAEA safeguards or the Nuclear Suppliers' Group.

Following the collapse of the Soviet empire, serious concerns were raised regarding the security of Russia's nuclear weapons, weapons usable materials, and nuclear weapons experts. It is generally believed that Russia's nuclear weapons are more secure than its weapons usable materials. But there is much more weapons usable material **not in** weapons than **in** weapons. Hundreds of tons of these materials are stored at dozens of sites across Russia. The amount continues to grow as more and more Russian nuclear weapons are dismantled and the nuclear materials recovered. Meanwhile, production reactors in Russia continue to produce plutonium. There are also considerable quantities of weapons usable materials, for example left in Soviet era research reactors, in countries other than Russia that were formerly part of the Soviet Union.

There have been several reported cases of the theft of weapons usable materials within Russia, and several documented cases of nuclear smuggling out of Russia. The total amount of weapon usable materials successfully smuggled out of Russia cannot be accurately known. There are also documented cases of the theft of radioactive isotopic sources, including within the United States. Again, the actual numbers and types, and where the sources finally ended up, cannot be accurately known.

Since 1992 the Nunn-Lugar program has financed cooperative efforts to dismantle Russian nuclear weapon delivery systems and secure nuclear weapons and materials. Since 1994 the Department of Energy (DOE) and the National Labs have worked with their counterparts in Russia to secure nuclear materials and weapons under the Materials Protection, Control and Accounting (MPC&A) program. Today, under the DOE National Nuclear Security Administration (DOE NNSA), this and related programs such as the HEU purchase agreement, have helped secure amounts of weapons usable nuclear material equivalent to thousands of nuclear weapons. The magnitude of the problem is daunting. DOE NNSA estimates indicate approximately 600 tons of weapons usable materials located at 95 sites, or, considering the IAEA definition of significant quantities, enough material to make more than 40,000 nuclear explosive devices. Rapid progress is being made to increase the security of these materials, but completing the effort will take several more years of intensive work.

Another DOE NNSA sponsored program, called the Second Line of Defense, is working to install detection systems at transit points in Russia and neighboring countries to detect smuggled nuclear materials. These systems include monitors for air, rail and ship cargo looking for concealed nuclear materials.

Since September 11, the DOE NNSA has been working with its Russian counterpart, the Ministry of Atomic Energy (MINATOM), to extend the MPC&A and Second Line of Defense programs to include radiological sources as well as weapons usable materials. In general, the intention is to find new ways to work together to combat nuclear terrorism. Clearly, securing Russia's nuclear materials and enhancing security at borders and transit points are important elements of a comprehensive approach to combating nuclear terrorism, based on a protection strategy that is multi-layered and provides defense in depth.

One key to enabling such a multi-layered, defense-in-depth strategy is improved detection technology. The underlying physics of detecting the presence of nuclear materials has been known for decades. Measurable signatures include gamma rays from radioactive decay, and both gamma rays and neutrons arising from spontaneous fission. Isotopic and accelerator based sources of energetic X rays, gamma rays, and neutrons can be used to detect the presence of weapons usable materials by measuring the emanations from induced fission. Today, building on the availability of new detector materials, advances in electronics, and miniaturization of processors and memory, sophisticated hand held and portable sensors and detection systems are becoming available. Based on these advances, many U.S. Customs agents are equipped with hand held radiation pagers, small devices that can detect sources of radiation, if in sufficiently close proximity. New, more sensitive detection technology is being evaluated at entry points into the U.S. to look for nuclear contraband carried by people, hidden in luggage, within vehicles, or in cargo. While the state of technology can support the eventual wide deployment of such systems, the cost will be high and, of course, no system can ever be foolproof.

If the worst occurs and a nuclear-related terrorist attack becomes a reality, whether involving an RDD or an IND, it will be up to local, state and federal emergency response authorities to deal with the crisis. The DOE's Nuclear Emergency Support Team (NEST) will be in the vanguard. NEST actually consists of several interrelated capabilities, including assessing the credibility of the threat, searching for and rendering harmless a nuclear terrorist device, and helping to mitigate the consequences to public health and the environment. The men and women of NEST consist largely of volunteer experts from the National Labs. They represent a critical core of expertise for responding to a nuclear terrorist attack.

However, more capability to combat nuclear terrorism is needed, considering the urgency of the threat post-September 11 and the potentially disastrous consequences of a nuclear terrorist attack. Preventing a nuclear terrorist device from entering the U.S. or being placed in an urban area represent major challenges. If such an attack ever occurs, screening the health effects of potentially thousands of people exposed to radiation and cleaning up widely contaminated areas may represent even greater challenges. The scientific and technical base of the country is needed to address these challenges.

Historically, physicists have been in the vanguard of understanding "things nuclear", including technical measures on behalf of nuclear arms control and limiting nuclear weapons proliferation. It is now time for us to take on the challenge of combating nuclear terrorism.

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Radiological Terrorism

Steven E. Koonin

(Statement delivered before Senate Foreign Relations Committee, March 6, 2002)

The events of last fall have induced us all to give greater attention to the safety and defense of the civilian population. Unfortunately, this is a very difficult problem. Because the number of targets is virtually unlimited and the resources available to protect them are necessarily finite, hard choices have to be made about *what*, and *what not*, to protect, as well as what to protect *against*.

Of course, not all threats are equal. In allocating defensive resources, the factors to consider include the direct and indirect consequences of a successful attack, the likelihood of an attack, the vulnerability of the target, intelligence and warnings of potential attacks, and the availability of effective defense measures. I applaud the initiative of this Committee in defining and addressing these very important issues.

In that context, I want to call to your attention one type of terrorist attack that I believe to be a very serious threat: the deliberate dispersal of radioactive materials. These materials might be the weapons-grade metals used in nuclear weapons or the more common materials contained in radiation sources. The dispersal can be accomplished either through an explosive release (a nuclear device producing "fallout" or a conventional explosive that has been laced with nuclear material) or through a covert, and perhaps gradual, release of particulates, aerosols, or contaminated materials such as food. While the intent of the perpetrators might be to induce immediate or long-term casualties, far more widespread will be the intense psychosocial reactions associated with radiation. In any case, a large-scale release of radioactive material could well entail significant costs through both direct clean-up expenses and the economic disruption induced. My goal here is to describe for you the potential threat that I see and offer some possible steps that could be taken to reduce it.

My scientific credentials for this task are as follows. I am Professor of Theoretical Physics at the California Institute of Technology, as well as that institute's Provost. For more than 30 years, the focus of my teaching and research has been in nuclear physics and I am the author of some 200 refereed scientific publications in that field. I have also served as the Chair of the Division of Nuclear Physics of the American Physical Society. Beyond my academic credentials, I have been involved in National Security matters for more than 15 years. I currently chair the JASON group of academic scientists and engineers, which has a 40-year record of unbiased technical advice to the government on national security matters. I have also served on both the Pentagon's Defense Science Board and the Navy's CNO Executive Panel, and also chair the University of California's committee overseeing the national security aspects of the Los Alamos and Lawrence Livermore National Laboratories. More specifically related to counter-terrorism, I led a DARPA-chartered JASON study of Civilian Biodefense issues in 1999, and served this Fall on Defense Science Board panel looking broadly at terrorism vulnerabilities. While my testimony is informed by these experiences, particularly discussions with my JASON colleagues, the words and opinions expressed are my own.

Radioactive materials are common in society. Their importance in medical diagnostic and therapeutic procedures is well-known. Less well known, but equally important, is the use of intense radioactive sources to sterilize food and medical instruments and to image industrial equipment (including the logging of oil wells). Far less potent amounts of radioactive materials are used in smoke detectors, anti-static devices, and self-illuminating exit signs. Many of these sources are harmless and have no potential for terrorist misuse. There is also a very large amount of radioactivity contained in the spent fuel in the cooling ponds at nuclear power reactors.

Sources ranging from a few to thousands of Curies could be employed for terrorist purposes. If just three Curies (a fraction of a gram) of an appropriate isotope were spread over a square mile, the area would be uninhabitable according to the recommended exposure limits protecting the general population. While direct health effects would be minimal (for each 100,000 people exposed, some 4 cancer deaths would eventually be added to the 20,000 lifetime cancers that would have occurred otherwise) the psychosocial effects would be enormous.

I believe that radiological terrorism is a plausible threat. Gram for gram, radioactive material can be at least as *disruptive* as weaponized anthrax. Further, the material circulates broadly through society. There are tens of thousands of significant, long-lived sources in the US and many more abroad; they are produced, purchased, stored, and transported through ordinary channels. The expertise to handle them is widespread and/or readily acquired (radiation safety courses are offered regularly; you can sign up on the web). And the safety and security of these materials relies on the good faith and good sense of the end-users, who are licensed by the Nuclear Regulatory Commission. This array of facts does not leave me with a great deal of comfort.

One scenario of how a terrorist attack using radioactive material materials might play out is as follows. A several-curie source of a long-lived isotope is stolen and covertly released one evening throughout the business district of a major city. Acting on an anonymous tip the next morning, officials verify widespread contamination over a 100 block area at roughly three times the natural background level, well above the legal exposure limit protecting the general population. That area is immediately evacuated and sealed off as hundreds of thousands of people rush to hospitals demanding to be screened. Businesses in the area are shutdown during the many months of decontamination that follow; dozens of buildings are razed. Economic damage runs into the billions of dollars, but there are no direct fatalities.

Most important in thinking through the situation are the widespread fear of radiation and the low legal dose limits protecting the general population. These latter make the terrorists' task easier in at least two respects. First, even very low levels of contamination, comparable to the natural background level in many locales, will be very disruptive. Second, in decontaminating any site, the question of "How clean, at what cost, and in what time?" will eventually have to be answered; that will not be easy.

There are several kinds of measures that can be taken to prevent terrorist attacks using radioactive materials, or at least make them more difficult to carry out. Through various economic, regulatory, and technological mechanisms, one can encourage migration of legitimate users from radioactive sources to radiation sources that can be turned off, such as accelerators and electrically-driven neutron generators. However, this will not be possible for all applications. Strengthened controls on radioactive materials are therefore an important step; fortunately, some of the infrastructure is already in place through the NRC and the IAEA. Also important would be the establishment of pathways to retrieve, store, and dispose of unwanted radioactive materials. The tracking of personnel with radiation expertise also seems a good idea, as this would provide both a registry of trained responders in the event of an incident, as well as be of assistance in detecting terrorist preparations.

Widespread radiation monitoring to detect large sources as they are moved about would be very useful. One would start with ports of entry, transportation choke points, rail plane, and ship cargo, and mail. Going further, it is not difficult to imagine widely deployed radiation detectors ("one on every lamp post"). In contrast to detectors for biological and chemical agents, the monitoring technology is well-established, the power and maintenance requirements are likely to be minimal, and the specificity and robustness will be high. Whatever the character and extent of radiation monitoring, it will be important to significantly test and "red-team" the system.

Before an incident occurs, it is important to educate the first responders and the public as to the nature of this threat, the probable consequences an incident (*i.e.*, few casualties, maximal disruption), and how they can be managed. This will likely not be simple given the unease evident in many public discussions of radiation.

In summary, I believe that the deliberate dispersal of radioactive materials is a significant and plausible threat. However, it is very likely that the predominant effects will not be casualties, but rather psychosocial consequences and economic disruption. Fortunately, there are a number of steps that can be taken to reduce the likelihood and impact of such an attack, beginning with the strengthening of controls on radioactive materials.

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Does New Nuclear Posture Review Foster Proliferation of nuclear Weapons?

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The Bush administration's new Nuclear Posture Review (NPR), which was leaked to the LA Times, proposes measures that, in the view or many physicists, would mark a dangerous step backward in nuclear weapon doctrine and policy.

During much of the Cold War, the US threatened to initiate use of nuclear weapons if conventional forces could not repel a Soviet invasion of Western. With the collapse of the Soviet Union, this policy lost whatever rationale it may have had. Never the less, the opportunity to adopt a No First Use policy was not exploited. Furthermore, the Clinton administration was deliberately ambiguous about whether it might use nuclear weapons in response to a chemical or biological attack.

The new Bush NPR goes much further. It would enlarge and amplify the role of nuclear weapons by intermingling nuclear and conventional forces and command and control; designing new nuclear weapons; and readying the Nevada test site for testing on much shorter notice.

The policies advocated in the Bush NPR pose a grave threat to the nonproliferation regime and the Nuclear Non-Proliferation Treaty (NPT) on which the regime is based. If the US were to resume testing, other states with far less mature, or none,should be expected to follow suit. Furthermore, in gaining the indefinite extension of the NPT in 1995 the US committed itself to the Comprehensive Test Ban Treaty, which the Bush administration opposes. The NPR proposes contingency plans for pre-emptive nuclear attacks on states that do not have nuclear weapons, which contradicts security guarantees that were provided by earlier administrations, and which were also key to the indefinite extension of the NPT.

Finally, while the NPR confirms the administration's plan to cut the number of deployed strategic warheads to about 2000, it also intends to keep a large portion of the withdrawn weapons in a ready reserve. The Russians, and many others, in the U.S. and abroad, proposed instead to render these cuts irreversible and verifiable.

In short, when the state with the world's most powerful nuclear and conventional forces announces that it must retain a huge nuclear arsenal into the indefinite future, still needs new nuclear weapons, and is laying plans to possibly use nuclear weapons against basically weak opponents who may not even have nuclear weapons, is it not constructing a compelling brief in favor of nuclear proliferation ?

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