The International Sakharov Conference -- Panel 4

A Harvard University Conference celebrating the 40th anniversary of Andrei Sakharov's 1968 essay *Reflections on Progress, Peaceful Coexistence, and Intellectual Freedom* was held on October 24-25, 2008, at the Norton's Woods Conference Center, Cambridge, Mass. The Conference was organized by the Davis Center's Sakharov Program on Human Rights, the Physics Department, and the Andrei Sakharov Foundation (USA).

The Conference's Panel 4 "Andrei Sakharov's Nuclear Legacy" was cosponsored by the American Academy of Arts and Sciences and featured physicists from America and Russia discussing issues connected with the peaceful use of atomic energy and with the control of nuclear weapons in language understandable by non-specialists.

Panel 4 -- Andrei Sakharov's Nuclear Legacy

The panelists and their topics were:

Paul M. Doty – Chair

Matthew Bunn – The Future of Nuclear Energy

Frantisek Janouch – Nuclear Energy in Europe

Evgeny Miasnikov – Control and Reduction of Nuclear Weapons

Pavel Podvig – Missile Defense Systems

PANEL 4

Emilio Bizzi – *A neuroscientist and Institute Professor at the Massachusetts Institute of Technology (MIT), he is* p*resident of the American Academy of Arts and Sciences.*

Good evening. I would like to welcome you all here. The Academy is pleased to be the site of this conference and to collaborate with its sponsors, Harvard's Department of Physics, the Sakharov Program on Human Rights, and the Andrei Sakharov Foundation.

Andrei Sakharov was an esteemed foreign honorary member of this academy. Soon after his important essay *Reflections on Progress, Peaceful Coexistence and Intellectual Freedom* was published in 1968, a meeting at the Academy discussed it, and when Sakharov left the Soviet Union for the first time in November 1988, his first press conference was held at the Academy.

Much of Sakharov's work parallels the Academy's long-standing focus on arms control, nuclear energy and nuclear weapons. This work continues with the Academy's new project, The Global Nuclear Future Initiative. This project is aimed at identifying ways to ensure that the global spread of nuclear energy does not result in corresponding increases in nuclear proliferation. This project is led by Steve Miller of Harvard University and Scott Sagan of Stanford University.

I want also to acknowledge Professor Richard Wilson, who was instrumental in conceiving this conference.

And now it's my pleasure to introduce Professor Paul Doty who will chair this evening's program. Paul's career has developed along two tracks. One has been in biochemistry. He founded the Harvard University Department of Biochemistry and Molecular Biology. And the other track is in science policy and international security studies. Paul founded the Center for Science and International Affairs at the Kennedy School of Government in 1974, and he is now the Center's Director Emeritus. At the same time, he has been a major player in the creation of the Academy's Committee on International Security Studies. As a graduate student, he was assigned to the Manhattan Project, an experience that inspired his lifelong work aimed at averting nuclear war. He served in government, as a Special Assistant to the President on National Security, and as a member of the President's Science Advisory Committee and the President's Arms Control Advisory Group.

Paul, I'm pleased you've agreed to introduce and moderate this panel.

Paul Mead Doty – *A member of the National Academy of Sciences. Since attending the first unofficial meeting of nuclear scientists in Pugwash, Nova Scotia, in 1957, where he made contact with Soviet counterparts, Doty has travelled 42 times to the Soviet Union to promote informed examination of the technical aspects related to avoiding nuclear war.*

Thank you, Emil. The session this evening is on Sakharov's nuclear legacy. No one can have a greater legacy than Sakharov. The catalyst for his clarion call for a new world order committed to human rights and intellectual freedom was the hydrogen bomb. The climax was his design of the largest bomb ever built. It was tested in 1961, with a yield of more than 50 megatons. The explosive yield far exceeded that of all wars that had ever been fought.

Seven years later, in 1968, he wrote the essay which we celebrate today. And I will read you two sentences from it: "The technical aspects of thermonuclear weapons have made thermonuclear war a peril to the very existence of humanity. These aspects are: the enormous destructive power of thermonuclear explosions, the relative cheapness of nuclear-armed long-range missiles and the

practical impossibility of an effective defense against a massive missile attack."[1]

At that time, in 1968, the nuclear weapon inventory of the United States was about 30,000 weapons, and that of the Soviet Union was about 10,000. So now, forty years later, what is the situation? There has been some progress in controlling this build up, and there have been some new dangers. The numbers of weapons in the arsenals and the means of delivery have dropped from their peak by nearly a factor of eight, and the yield of the weapons in place has been reduced. And with the end of the Cold War, the threat of a large-scale exchange between the Soviet Union-Russia and the U.S. has greatly diminished. However, it has not vanished, as witnessed by the fact that each side has about 2,000 weapons on hair-trigger alert, pointed at each other. Such an exchange, although diminished from earlier times, would still risk ending a civilization that has taken thousands of years to build.

But there are new dangers. These are caused by new countries becoming nuclear-capable, albeit with much smaller stockpiles. These dangers are seen as much more likely to lead to nuclear use, perhaps by the new possessor countries, but more likely by terrorists who have managed to get hold of a nuclear weapon. With the increased inter-dependence of urban centers throughout the world, the loss of even one would be a catastrophe beyond anything that is in our experience.

So with this background I turn to the speakers today. There are four beside me. We are hoping that they may convey a flavor and an update of many aspects of what has been done to alleviate this great danger.

Matt Bunn, who will speak first, is a Harvard professor. I hesitate to summarize his accomplishments but will simply say that he has become a remarkable authority in all aspects of nuclear weaponry and its control, and more importantly, in the control of the essential fissile material that goes into nuclear weapons, this being the heart of how what I've just been speaking of might be controlled and eliminated.

So let's begin with that. The idea is that each will speak about 10 minutes, and if they have time they can discuss a bit among themselves or answer your questions.

Matthew Bunn -- *An Associate Professor at Harvard's John F. Kennedy School of Government, Bunn's research interests include nuclear theft and terrorism; control of nuclear proliferation; and the future of nuclear energy and its fuel cycle. Before joining the Kennedy School in 1997, he served for three years as an adviser to the Office of Science and Technology Policy. He is the author, most recently, of* Securing the Bomb, 2008.

[1] Andrei Sakharov, *Progress, Coexistence and Intellectual Freedom*, Alfred Knopf, 1968, p. 33.

Thanks very much Paul. I must say that it is more than an honor; it's very humbling to be speaking at a conference celebrating Andrei Sakharov. I certainly never aspired to play a role even remotely resembling the role that Sakharov played in the world. I'm going to try not to ask for more time, so I'll give you a once-over lightly of a lot of the important issues relating to the future of nuclear energy.

Let me first put it in a little bit of context. This is from a fairly-well-known science article from a few years ago, where Princeton professors Stephen Pacala and Rob Socolow basically argued that if we want to stabilize the climate, we're going to need seven "wedges" of growing contribution of carbon-free energy or efficiency.[2] To provide even one of those wedges, nuclear energy would have to grow from about 369 gigawatts today to over 1100 gigawatts in 2050. To get two wedges is probably unattainable, given where the nuclear industry is today.

For the last several years, even though we have been going through the beginnings of a nuclear energy revival in a number of countries, the actual reactors getting attached to the grid have been about four a year, and we need to shift to twenty-five a year every year from now until 2050 if we want to have even one of those wedges, if we want nuclear to be even one-seventh of the answer to the climate problem.

In order to do that, nuclear would have to be dramatically more attractive to governments and utilities than it has been in recent years. A major disaster, whether from accident or from terrorism, would doom any realistic prospect for that.

If nuclear is going to be attractive for the developed countries, it's very likely it will be attractive for developing countries as well. So large-scale growth implies spread. The Middle East, in particular, is a hotbed of interest in new nuclear power at the moment.

So there are a lot of issues that will have to be addressed, if nuclear power is going to grow enough to be interesting with respect to climate change: economics, safety, terrorism, proliferation, and nuclear waste disposal. I'm going to focus on safety, terrorism and proliferation, which are some key risks that large-scale growth of nuclear energy might pose.

First of all, how do we reduce accident risks even as we're growing nuclear energy? This was clearly a major concern for Sakharov in the aftermath of the Chernobyl disaster and all that implied. Nuclear power today is considerably safer than it was in the years of the Three Mile Island and Chernobyl accidents, and there are many quantitative indicators you can look at that

[2] Robert Socolow and Stephen Pacala, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science* 13 August 2004 pp. 968 – 972.

make that clear. Nonetheless, there are continuing issues. Some of you may have heard of Ohio's Davis-Besse Nuclear Power Station, where a nuclear reactor was allowed to run without inspections for a long period, and it turned out that boric acid dripping on the pressure vessel ate a football-sized hole in the head; only a quarter inch of steel remained to contain the pressurized water and avoid a massive loss of coolant.

So, to avoid increasing the accident risks as more nuclear power plants are put on line, institutional approaches to finding and fixing the highest accident risks have to be strengthened. There are probably today somewhere in the range of 20 to 40 reactors that are providing 80 percent of the total global percentage of risk. Most reactors are very safe. So it's a small number of reactors that aren't.

And then we need to strengthen the safety culture worldwide. That was a key problem at Davis-Besse. Currently the international safety regime is really not up to the task, and it needs to be strengthened. For example, the International Atomic Energy Agency (IAEA) reviews the safety of reactors, but they have reviewed only a fraction of the reactors in the world because they only review the ones that states ask them to look at.

All of the power reactors today are members of an industry group called the World Association of Nuclear Operators (WANO), but there are serious questions about the quality of the reviews of some of the regional groupings of WANO. I hesitate to say it, but the Russian-led grouping in particular has been criticized for giving high grades to reactors that are in very bad shape.

Recently the IAEA put together what they called the Commission of Eminent Persons with which I was I was associated, and they recommended binding global standards for safety and IAEA safety reviews for all power reactors.

Nuclear terrorism is another very real danger. Some people ask: how could guys in caves do what the Manhattan Project did? The reality is that Mother Nature has been kind to us in that the essential ingredients of nuclear weapons don't exist in Nature and are hard to produce, but, unfortunately, cruel to us in that once you get hold of them, it's not as hard to make a nuclear bomb as we would like. If you have highly-enriched uranium, making a crude explosive is simply a matter of slamming two pieces together at sufficient speed. I put out an annual report on how we're doing locking down nuclear stockpiles around the world that might be used for nuclear weapons.[3]

Al Qaeda has been very focused on attempting to get nuclear weapons. I have a sketch seized

[3] The full report *Securing the Bomb 2008* is available at http://www.nti.org/e_research/Securing_the_bomb08.pdf .

from a safe house in Afghanistan -- it's not a very good sketch – which shows they were trying to make a gun-type bomb out of plutonium. That wouldn't work. Nevertheless, this is something Al Qaeda has been focused on. They have also looked at sabotaging nuclear reactors; they considered doing that as part of the 9/11 attack, but decided to postpone it for another day.

So we need to move quickly to reduce the risk of terrorists turning a modern city into a new Hiroshima. We need a fast-paced global campaign to put effective security in force for every place where there's a nuclear weapon or a significant cache of nuclear materials, whether in a developing country, a transition country or an advanced country. There are some advanced countries where it is still against the rules to have armed guards at any nuclear facility even if there are hundreds of kilograms of highly-enriched uranium there. We need to establish effective global nuclear security standards; there are no binding global standards currently in place for how secure nuclear weapons and materials must be kept. We need to consolidate this stuff at the smallest practical number of sites. There are efforts underway to do that, but we need to expand the number of facilities those efforts cover, the kind of materials they cover, and the policy tools they use. Ultimately, we should seek over time -- and I know Professor Wilson will disagree with me on this -- to eliminate the civil use of highly-enriched uranium. Or -- an alternative that Professor Wilson would accept -- at least to have the highest practical level of security that we use in the military sector required for use in the civil sector as well. Today, that is certainly not the case.

We also need to deal with sabotage risks. We need to rapidly upgrade security for all the high-consequence nuclear facilities: the power reactors, the spent fuel pools, reprocessing plants and so on. Many of these today still do not have any armed guards on site, many of them do not have the kind of design that makes it impossible for one explosion to take out both of the redundant safety systems that were designed with safety in mind rather than with sabotage in mind.

Today, I would argue -- even though I don't have the numbers to back it up -- that we've done enough on safety; that today the probability of a really big release, a Chernobyl-scale release of radioactive materials, happening purely by accident is probably lower than the probability of it happening from sabotage, from somebody wanting to make it happen.

If that's true, we need a profound transformation in the way industry handles this kind of thing. Because in the nuclear energy industry today, everyone is trained every single day on safety from the day they enter the industry, but maybe they get a half hour briefing once a year on security. The level of thinking, the level of measures in place are just not remotely comparable. This is the issue of security culture. It matters. This is a propped-open security door that the United States had provided at a Russian nuclear facility. What's particularly remarkable is that there was a propped-open door when the U.S. investigators were there with their cameras; this means that the

personnel at that site didn't realize that it was wrong to prop open the security doors.

The other key issue is nuclear proliferation. If we're going to have a large-scale growth of nuclear energy, we want to make sure that doesn't lead to a large increase of nuclear weapons. It is not only that the expanded use of nuclear energy poses a risk of proliferation, but also that proliferation poses a risk to nuclear energy. If people perceive that lots of nuclear power plants mean lots of nuclear bombs, they're not going to buy the number of nuclear power plants that would allow nuclear energy to be a significant player in addressing climate change.

It's true there are major challenges to the nonproliferation regime today, but the regime has been much more successful than many people realize. Twenty years ago there were nine states with nuclear weapons. Today, there are nine states with nuclear weapons. That's an amazing public policy success. North Korea added itself to the list. South Africa subtracted itself from the list. Think about that. It means we got through the collapse of the Soviet Union, all the chaos that followed, and the secret nuclear weapons programs in Iraq, Iran, and Libya, with no increase in the number of states with nuclear weapons. The whole period of the activity of Pakistan's A. Q. Khan's international network selling nuclear weapons technology with no increase in the net number of states with nuclear weapons. It's an amazing public policy success.

There are more states today that started weapons programs and verifiably agreed to give them up than there are states with nuclear weapons. That means we succeed more often than we fail. And yet there's enormous fatalism out there that says, "States that want nuclear weapons are going to get them eventually, there's nothing we can do." It's not true. We have been very successful over the years; there's a chance, if we take the policy steps that we need to take that we can continue that success. It's not going to be easy. The world has changed. Globalization, the spread of technology, but there is a chance and we can't be fatalistic. If we are fatalistic we will fail to take the actions that can reduce the risk.

The recent proliferation crises have taught us a lot of lessons about what those actions are. First, we need to engage the hard cases. Our failure in the Bush administration to engage seriously with North Korea and Iran has led North Korea to at least quadruple the amount of plutonium it has available for nuclear weapons, and it's led Iran to go from zero to almost 4,000 centrifuges operating at this time.

We need to beef up nuclear security as I mentioned earlier, to make sure that every nuclear weapon, every cache of plutonium or highly-enriched uranium is secure and accounted for. We need to strengthen nuclear safeguards. It's remarkable that today the IAEA's budget for safeguarding all nuclear material worldwide is about the same as the budget of the Indianapolis police department. The authority of the IAEA is remarkably limited as well. There's a lot that

needs to be done. I commend to you the recent study by the Commission of Eminent Persons.[4] There's a lot of interesting ideas in there on how to strengthen nuclear safeguards.

We need to take new steps to stop black-market nuclear networks. The A. Q. Khan network was operating in some 20 countries for some 20 years before it was taken down. That makes it clear that the global export control system is, using the word of the director general of the IAEA, "broken." There's a lot we need to do on international police and intelligence cooperation, on getting export controls in place. We've never before worried about export controls in countries like Malaysia or Dubai, which were key nodes of the A. Q. Khan network.

We need to do what we can to stem the spread of enrichment and reprocessing. This needs to be done carefully, because the last thing the non-nuclear weapon states are willing to tolerate is to divide the world again into haves and have-nots, the countries that are allowed to have enrichment and reprocessing and the countries that are not allowed to have them. But I think there's a great deal that can be done in providing really reliable assurances of fuel supply, assurances that spent fuel can be managed if you can send it away to someone else through a fuel leasing program, that will give countries incentives to chose voluntarily not to invest in their own enrichment and reprocessing plants. That's crucial because those are the key technologies that allow you to make nuclear bomb material. We need to toughen enforcement. When North Korea was first found to be in violation, in a fairly stark way, of the nuclear non-proliferation treaty in the early 1990s, the Security Council did a whole lot of nothing for many years. Even now, Iran is continuing to ignore the Security Council's legally binding requirement that it suspend its enrichment program.

Fundamentally, we need to reduce demand for nuclear weapons since all the other things only slow proliferation down. Convincing states that started nuclear weapons programs that it was in their interest not to have nuclear weapons is what has gotten us more states that gave up nuclear weapons programs than there are states that still have nuclear weapons. And there's a lot that has to be done there. For a start, ending our U.S. habit of reserving the right to invade sovereign states would be, in my view, a good way to begin in reducing demand. There was a senior Indian general who remarked that the lesson of the Iraq war was, "If you think you might end up on the wrong side of the United States, you'd better get nuclear weapons."

And fundamentally, we need to keep our end of the non-proliferation bargain, which means disarmament. It is very unlikely that we will get the support that is needed from the non-nuclear weapon states for all sorts of things that involve more inconveniences and more costs to them,

[4] See at http://www.iaea.org/NewsCenter/News/PDF/2020report0508.pdf .

tougher export controls, more stringent inspections and so on, if we are not willing to accept some constraints on our own nuclear policy.

Again, I believe that there is hope that if we put the right policies in place, twenty years from now, we may still have only nine nuclear weapon states, and maybe fewer.

So that really brings us to the challenge of disarmament, which we're going to hear more about from others later. Fundamentally, states that have nuclear weapons aren't going to give them up unless they think it's in *their* security interest to give them up. So we need to build a structure of international security that makes it in their interest. We need to rethink the risks of the status quo, of indefinite maintenance of large stockpiles of nuclear arms. This will require detailed analyses of how we get there from here, how we do the verification, and the verification is inevitably going to require societal verification, and not just satellites and inspectors. That gets us back to Sakharov, because it means it will require an unprecedented level of openness, of international cooperation, of freedom of thought, because people are going to have to say, "Even though it's my country that's doing this thing that I know is wrong, I will report it." That's an attitude that doesn't exist today in many countries -- it will have to be built over time.

In short, we need a new nuclear order that involves more transparency, more openness, more international cooperation, stronger international institutions, reduced numbers and readiness of nuclear weapons,. I'd like to see all nuclear weapons taken off quick reaction alert, and if we can put all those institutions in place, a growing contribution from safe, secure, and peaceful nuclear energy. We don't know yet whether we can or cannot solve the climate problem without nuclear energy, but it will certainly be a lot harder if we don't have a contribution from nuclear energy. It is the largest source of base-load, low-carbon electricity supply that can be readily expanded that we've got available today.

Paul Doty
Our next speaker is Frantisek Janouch, a Czech citizen who commutes between Prague and Stockholm. He has been for some time a visiting professor of nuclear physics in Stockholm. He will tell us about the status of nuclear power in Eastern Europe.

Frantisek Janouch – *After protesting the 1968 Soviet occupation of Czechoslovakia, Janouch was fired from his position as head of the Theoretical Nuclear Physics Department at Prague's Nuclear Research Institute. In 1973 he was permitted to emigrate, and he was appointed a visiting Professor of Physics at Stockholm's Royal Institute of Technology. In 1978, Janouch organized Foundation Charter 77 to support dissidents in Czechoslovakia and is currently its Chairman. He is the Coordinator of the Nuclear Energy Forum, which convenes in Prague.*

Let me begin with a little background about myself: for several years I was unemployed in Prague for political reasons. In 1973, with an invitation from the Royal Swedish Academy, I left Czechoslovakia for Sweden. In 1975 I was stripped of my Czechoslovak citizenship.

My first article published in Swedish in 1975 was entitled "Energy, Freedom, and Independence." I had a lot of discussions with my Swedish friends and Swedish politicians about its content – they could not grasp how energy could be linked with such "abstract" terms as freedom, and independence. Thirty year later, the situation has changed dramatically: politicians and people in the West now understand much better that our freedom and our political independence are very much related to the energy needed to keep our societies running normally, so the relationship is seldom questioned. What still is questioned, however – at least in some countries –is where to get our energy: coal, LNG, wind, sun, or nuclear.

When I came to the West I was invited by many leftist and environmental groups to lecture about energy. In the mid-1970s many of these leftist and green environmental groups assumed that I, a dissident, would support their struggle against nuclear power. When I didn't, they would say, "We didn't expect a dissident, to defend nuclear energy. That may be your opinion, but what would Andrei Sakharov say about nuclear energy?" My answer: "Andrei Sakharov is a physicist, so he would certainly have views similar to mine. But I cannot speak for him."

That is why, in 1976, I contacted Sakharov through our "dissident post." I explained why he should formulate his attitude toward nuclear energy in a short article, understandable to both the general public and to politicians. I told him that such a statement would be important for Western countries. In December 1977, I received a four-page, hand-written paper from him. At the end, he added a note: "For Frantisek, with best wishes and with feelings of solidarity. I think this paper should be published in a several countries. Andrei Sakharov."

In 1977, Westerners, and especially U.S. "dissidents" -- by that I mean protesters against the war in Vietnam – suddenly felt themselves unemployed and useless. The Vietnam War was over. They did not know where to direct their tremendous social power: hundreds of thousands, perhaps millions, of young people, full of energy and enthusiasm, believing in freedom, justice, and a better, socially just future.

Unfortunately, with the encouragement of Jane Fonda and individuals from Greenpeace, the young "unemployed" started to direct their energy against the peaceful use of nuclear power. It was not against the stockpiles of nuclear weapons, at that time consisting of tens of thousands of nuclear bombs, many of which were a thousand times more powerful than the Hiroshima bomb!

I translated Sakharov's article and sent it to *Der Spiegel*, one of the largest and most respected journals in Germany, and simultaneously to the *Bulletin of the Atomic Scientists*. I knew the editors-in-chief of both journals personally. To my great surprise and disappointment, the editors of both publications were infected with anti-nuclear ideology. They refused to publish Sakharov's article because they did not believe it was written by Andrei Sakharov. Only after I sent a copy of Sakharov's manuscript with his handwritten note to me did the editors change their minds and publish his paper: in fact, the *Bulletin of Atomic Scientists* printed it as a lead story and used a green front cover for the issue.[5] Sakharov's paper was subsequently published in key newspapers and journals around the world. It is interesting that thirty years later nuclear power is considered, at least by most reasonable and educated people, as one of the "greenest" energy sources.

Andrei Sakharov was very clear about the importance of nuclear energy; he connected nuclear energy with freedom in the West. Today, this wisdom and knowledge are slowly returning to Europe and the United States. Many people still do not fully understand that nuclear energy provides much more security and safety than oil, natural gas, or coal, of which the supplies can easily be blocked.

Many years ago the European Parliament established the Andrei Sakharov Prize for Freedom of Thought, which is awarded yearly to distinguished human rights activists. The European Union also provides support, with billions of Euros to another large international project: research to develop a fusion reactor based on Sakharov's Tokamak idea.

In spite of Sakharov's fame (and his Nobel Prize), for almost thirty years the West neglected Sakharov's clear warning that nuclear energy provides a certain degree of freedom and security for the West. Most European and American politicians do not understand that energy in nature is produced only by fission or fusion – even geothermal heat is produced by the decay of radioactive nuclei located inside the earth.

By 1986, Sakharov's paper "Nuclear Energy and the Freedom of the West" had been published in at least ten countries. The paper caused a conflict between Heinrich Böll and Sakharov, with Böll writing an open letter to Sakharov, Sakharov answering with one, and so on. At the time, although Western Europe was hesitating whether or not to go nuclear, the USSR and Eastern Europe were doing so. In 1986, two months after the Chernobyl disaster, the Swedish Foreign Policy Institute published my booklet on nuclear power in the Soviet Union and Europe entitled

[5] Andrei Sakharov, "Nuclear Energy and the Freedom of the West," *Bulletin of the Atomic Scientists*, June 1978.

"In the Shadow of Chernobyl;" my original title had been "The East Goes Nuclear."

Andrei Sakharov left us prematurely in December 1989. In May 1991 a large international Andrei Sakharov Memorial Congress was convened in Moscow. Richard Wilson and I co-chaired two or three sessions on nuclear energy at the Memorial Congress. Before the Congress, Dick and I met in Kiev, and we visited Chernobyl. We spent a night there, and we were allowed to go inside the sarcophagus. Dick had a dosimeter with him and was frequently taking measurements. (I remember that we had to shower carefully afterward.) We had a number of enlightening discussions with nuclear specialists in Chernobyl. In Moscow, we tried to persuade the Sakharov Congress that nuclear energy is an important part of the world energy supply.

It is difficult now to split Europe into East and West, new and old. The European Union is today the largest producer of nuclear power; it produces eight times more nuclear-generated electricity than North America, three times more than Japan, and almost seven times more than Russia. Four EU countries use nuclear power plants for more than 50 percent of their total electricity production. In the EU overall, 35 percent of electricity production is from nuclear power.

Nuclear power is attractive for several reasons: nuclear reactors are safe; nuclear power is the cheapest way to produce electricity; investments in built reactors are mostly amortized; nuclear energy has a stable cost structure; nuclear power plants can be and are modernized at reasonable cost; and plant lifetimes are on the order of sixty to seventy years.

Thirteen countries in Europe are using nuclear energy -- Bulgaria, the Czech Republic, Finland, France, Lithuania, Hungary, the Netherlands, Romania, Slovakia, Slovenia, Greece, Great Britain, and Switzerland. Four countries are planning to phase out nuclear energy. (There were 5 countries, but Great Britain has reversed its decision, and is collaborating with France.) Sweden and other countries may reconsider their decision to stop using nuclear energy. And four additional EU countries plus Turkey are ready to join the nuclear club and build nuclear power plants.

The European Nuclear Energy Forum (ENEF) was established recently by the European Commission to promote nuclear power in Europe. At its first meeting in Prague in May 2008 there were more than 250 participants, among them six prime ministers. All participants received Sakharov's paper, together with background information. The Forum will meet twice a year, alternating between Prague and Bratislava. I was nominated coordinator of the Prague sessions by the Czech government.[6] I believe that these regular meetings will support the renaissance of

[6] For more on the May meeting see http://ec.europa.eu/energy/nuclear/forum/meetings/2008_may_en.htm

nuclear power in Europe.

I think that the plans to increase the use of nuclear energy are impressive in Eastern Europe, France, Great Britain, Italy, Russia, India, and especially in China. After thirty years, Sakharov's prophecy is on its way to being understood and fulfilled in Europe.

Paul Doty

Our next speaker is Evgeny Myasnikov. He's not a stranger here, he's been at MIT, but his home is Moscow and his center of work is at the Arms Control and Environmental Energy Institute there. He's an expert in a whole range of nuclear weapons problems and their reduction.

Evgeny Myasnikov – *A senior research scientist at the Center for Arms Control, Energy and Environmental Studies of the Moscow Institute of Physics and Technology. Author of numerous papers on arms control, the most recent "US-Russian Strategic Arms Control After 2009: Room For Compromise?" (with Anatoly Diakov).*

Andrei Sakharov understood well the consequences of a global nuclear war. In his 1968 essay, he assigned primary importance to this threat. In order to avoid disaster, he urged mankind to overcome its divisions as an initial step back from the nuclear brink.

Sakharov wrote that certain changes must be made in the conduct of international affairs. He believed in systematically subordinating all other aims and local issues to the primary task of preventing aggravation of the international situation. Peaceful co-existence should be pursued and expanded to a level of cooperation in policy-making so that its immediate and long-term effects would neither sharpen tensions nor create difficulties for either party that would strengthen the forces of reaction, militarism, nationalism, fascism, or revanchism.

I think Sakharov's ideas are still key to finding our way toward a nuclear-weapons-free world. Where were we forty years ago and where are we now in terms of reducing the risk of nuclear war between the United States and Russia?

Let me briefly remind you of the facts. It took two decades from the publication of Sakharov's essay in 1968 to reverse the nuclear arms race and begin reduction. This was accomplished by painstaking work of diplomats, politicians and scientists who managed to establish a bilateral process of arms control negotiations. By the end of the 1980s, these mutual efforts brought both sides to the understanding that there were too many nuclear weapons in their stockpiles, and

significant, irreversible and verified reductions would benefit both sides.

This was the time when the United States and Russia signed the 1987 Intermediate-Range Nuclear Forces (INF) Treaty, which eliminated the total class of land-based nuclear weapon missiles of medium range. The Strategic Arms Reduction Treaty (START) cut the strategic nuclear weapons of both sides almost by half. In 1991, President Mikhail Gorbachev and President George H. W. Bush announced deep cuts of non-strategic nuclear weapons. At almost the same time, the two sides stopped nuclear testing and producing fissile materials for weapons purposes. Most important, serious cooperation began between the U.S. Department of Energy and the Russian Ministry of Atomic Energy. Perhaps the most significant achievement was the 1993 Russian-U.S. Highly Enriched Uranium (HEU) Agreement. Under this agreement, 500 tons of Russia's excess weapons-grade HEU are being blended down to low-enriched uranium, and then purchased by and shipped to the United States for making power reactor fuel.

Though nuclear reductions have been a bilateral process, perhaps most dramatic are the changes in the Russian arsenal. Russia has significantly reduced its strategic nuclear forces over the period of two decades, and this is due mostly to START. Although START was negotiated and signed during the Cold War, it continues to play a significant role, since the treaty has a robust and efficient verification system, which includes, among other things, twelve types of inspections, notifications, data exchange, and cooperative measures. START's verification mechanism provides a basis for retaining predictability and maintaining stability in U.S.-Russian relations. If START ends in December 2009, as it is slated to do, its verification mechanism and transparency will be lost.

Russia's stockpile of non-strategic nuclear weapons was never officially declared. According to our estimates that stockpile doesn't exceed 3,000 or 4,000 warheads, and it's diminishing. Russia also never released numbers on the quantity of HEU and weapons-grade plutonium it produced. The best estimates put Russia's stock of HEU at this time at 945 tons plus or minus 300 tons, and Russia's weapons-grade plutonium stock at 145 tons, plus or minus 20 tons, of which 34 tons were declared by Russia as excess for weapons purposes.

Nuclear arms reduction still has some momentum. Nevertheless the environment for this reduction is going to change. U.S. and Russian nuclear arsenals are going to be smaller but much less transparent. And there is a danger that the deterioration of transparency will spoil U.S.-Russian relations with more distrust and suspicion, and will kill many future mutually beneficial cooperation projects.

Why is this happening now, when neither Russia nor the United States is interested in beefing up

its nuclear forces? Andrei Sakharov raised a rhetorical question: of course it would be wiser to agree now to reduce conventional weapons and to eliminate nuclear weapons entirely, but is that possible in a world poisoned with fear and mistrust? I think a similar question can be raised these days. You may argue that in the late 1980s, when the Soviet Union and the United States concluded several arms reduction agreements, there was even deeper mistrust than now. This is true. But at that time, both sides felt that they had too many nuclear weapons and both thought that they had more to gain than to lose if they reduced their nuclear arsenals. This doesn't seem to be the case these days with respect to the Russian side. Almost ninety percent of Russian nuclear forces are still the legacy of the Cold War and the heritage of the Soviet Union. The current rate of retirement of strategic systems is significantly higher than the rate of new production. And this trend is going to last for at least the next 10 years. Russian policy-makers feel more and more concerned about the survivability of the future remaining forces. That's why there is such strong opposition to U.S. plans to deploy ballistic missile defenses in Europe and why Russia is so much concerned about U.S. reluctance to set limits on development of conventional, precision-guided strategic weapons. Russia perceives both of these U.S. actions as building up counterforce capability aimed at Russia's nuclear forces.

In this context, it's interesting to recall the views of Sakharov regarding ballistic missile defenses, conventional capabilities, and the nuclear arms reduction process. It's well known that Sakharov was very skeptical about ballistic missiles. He urged limiting their deployment. What I find interesting is that Sakharov also advocated the importance of taking account of the parties' comparative strength in conventional weapons in negotiating nuclear reductions. Sakharov was also a proponent of a balanced approach in nuclear reductions. In fact, ignoring these principles will make deeper cuts of nuclear weapons impossible. This is already happening these days as the United States and Russia discuss the future of START.

We know that the discussions are going on, but at a very slow pace, and we heard recently that the next round will begin this November. Although these discussions are confidential, from leaks to the press it's quite straightforward to find out the areas of disagreement. The hardest problem, I think, is to define the scope of the Treaty. For example, should it include only operationally deployed nuclear warheads, as the United States insists? Or should it also limit all deployed strategic systems as START did and as the Russian side wants?

Before I finish let me say a bit about negotiating attitudes. For the time being, Russia plays an active role in stimulating the dialogue. In fact the Russian side still wants to discuss a broader agenda than the U.S. side, covering the whole list of issues of strategic stability, which includes limits on strategic delivery systems, missile defenses, conventional precision-guided weapons, anti-submarine warfare, and space weapons. This is about renewing a dialogue that was cut short

after the Bush administration came to power in the year 2000. For well-known reasons, they were not interested in discussing this broad agenda with the Russians, but only in perhaps separating the verification system of START (leaving aside its limitation) and linking up this system to the Moscow treaty. But this is exactly what the Russian side wants to avoid.

Will a new administration be interested in reviving the arms control dialogue with Russia? There is hope, but this is an open question. There is, however, another difficult question that is rarely asked: Will the Russian side keep its positive attitude towards arms-control dialogue with the United States in the future? In my opinion there is a strong possibility that Russia will lose its interest in such a dialogue. Its nuclear forces will be smaller than now, but survivability of this smaller force will be insured by minimizing their transparency. Russia, might take an approach similar to China's, for example. If this happens, certainly we will have to forget about mutual inspections, notifications, and limits on deployment. At best, with regard to strategic forces, the situation will become similar to that of tactical weapons. But there is a prominent exception. Strategic forces will be on high alert ready to eliminate the other side within minutes.

Paul Doty

And now we turn to Pavel Podvig. He is Russian, but he has gone through the paces here at Princeton and MIT, and now he resides at the International Security program at Stanford University. He is going to go back to the missile program and his current irritations, and we look forward to his remarks.

Pavel Podvig – *A 1988 graduate of the Moscow Institute of Physics and Technology, he served as editor of* Russian Strategic Nuclear Forces *(2001). Podvig is currently a Research Associate at Stanford University's Center for International Security and Cooperation.*

I will focus on Sakharov's role in the missile defense debate. As you know, the subject just doesn't want to go away. Missile defense is a fairly complex, challenging issue if you take it in the context of the nuclear confrontation. It is only appropriate that Sakharov was part of that discussion.

Sakharov's involvement in this particular issue began in the late 1960s, and it wasn't the first time that he took a strong position on an issue. We know that he was very active on the issue of nuclear tests in the atmospheric. But when the missile defense issue came forward around 1967, his involvement was a bit different. His contribution at the time was a letter he wrote to the

Politburo on missile defense, arguing that the Soviet Union should take the U.S. offer that was on the table at the time -- or was discussed at the time -- which would limit missile defenses.

If you step back a bit and look at the context of this, it was a time of a very heated debate among the Soviet military, the military industry, and the political leadership about military strategy and the way the Soviet Union should build its nuclear forces.

What's interesting is that scientists were actively involved in that debate. Sakharov himself refers to his colleagues Khariton and Zababaikhin as contributing to the discussion. It was a closed discussion, but I believe the problem was that while the participating scientists were apparently quite skeptical about the potential of missile defenses, their impact was not as great as they probably hoped for, and not as great as in earlier discussions of military issues. The military industrial complex in the Soviet Union was growing stronger and assuming control of these issues.

In that discussion, scientists made a strong case that the Soviet missile defense program at the time was very problematic. But the Soviet leadership and the military industry were not particularly interested in taking any steps to limit the defenses. As far as we can tell, what was important for Sakharov and for some of his colleagues at the time was that the leadership was not interested in taking the opportunity to reduce the danger of nuclear war by limiting offensive nuclear forces and starting nuclear disarmament. That was probably why Sakharov tried to go beyond the closed discussion within the military industrial complex to make his case. An article on the subject by Sakharov and Ernst Henri was not printed in a Soviet newspaper. Mikhail Suslov [a member of the Politburo and its chief ideologist] found it unsuitable for publication.[7] This reinforced Sakharov's perception that the leadership and the military industrial complex were not particularly interested in reducing the danger of nuclear war.

Maybe that wasn't the main reason for Sakharov to go public with his views, but it certainly was one of the reasons as far as I can tell. In his 1968 *Reflections*, the anniversary of which we are celebrating today, he specifically mentioned the dangers of the nuclear arms race and the role that missile defense could play in that process.

Now let's skip quite a few important years, and go to the next stage in the missile defense debate, namely the Strategic Defense Initiative (SDI), the Star Wars Program that appeared in 1983. By that time, Sakharov was no longer an insider. He was in Gorky, in exile, but he was a very

[7] But the article which took the form of a dialogue between Sakharov and Soviet journalist Ernst Henri appeared in the samizdat journal *Politicheski dnevnik,*no. 30, March 1967, and in English, entitled "Scientists and the Danger of Nuclear War," in Stephen Cohen, editor, *An End to Silence*, Norton, 1982, pp. 228-234.

visible outsider. When Gorbachev, came to power, in 1985, he saw that the Soviet military complex was very happy about Star Wars since it gave them an excuse to push for a similar Soviet program. Besides, conventional wisdom in Soviet diplomatic and military circles was that as long as SDI was out there, the Soviet Union couldn't limit or reduce its offensive nuclear forces. Gorbachev tried to counter that pressure by convincing Reagan to discontinue SDI. He failed, most spectacularly, if you will, in Reykjavik, in October 1986.

It's not entirely coincidental that Sakharov was released shortly after the Reykjavik summit, because human rights issues were an important part of the meeting between Gorbachev and Reagan.

Sakharov was still skeptical about the missile defense system: he was skeptical about the impact such systems could make and the extent they could be useful militarily. In fact, he was skeptical about all the fancy directed-energy weapon technologies even before Reagan announced them in March 1983. Sakharov criticized the whole idea of defense against nuclear weapons. At the same time, Sakharov was very critical of the Soviet position that linked reductions of offensive forces to the issue of missile defense -- he saw this as counterproductive. He criticized both sides, and he was very open about it. I should add that Sakharov was certainly not a pacifist at that time. Indeed, he saw value in nuclear deterrence and in strategic balance. In his 1983 letter to Sidney Drell, he wrote that if preventing a nuclear war would require fifteen more years of a nuclear arms race, so be it! Preventing nuclear war was a priority issue for him.[8]

On some occasions, Sakharov advocated putting pressure on the Soviet Union to force it to restrain expansion of its nuclear programs. But what's interesting -- and what's important -- is that he never advocated using missile defense as a bargaining chip or as a means to apply pressure. As far as I know, he never suggested that the United States use missile defense or the threat of a missile defense to influence Soviet decisions at the time.

In February 1987, two months after Sakharov was released from his Gorky exile, the Moscow Forum for a Nuclear-Free World and the Survival of Mankind resulted in another interesting document. Frank von Hippel and Jeremy Stone met with Sakharov in his apartment, and the KGB transcribed their conversation. (For those of you who spoke with Sakharov in his apartment, KGB transcripts of your conversations probably exist as well.) Von Hippel and Stone tried to convince Sakharov that the Soviet Union should drop linking America's abandoning SDI

[8] "The Danger of Nuclear War: An Open Letter to Dr Sidney Drell," *Foreign Affairs*, Summer 1983, pp. 1001-1016.

and the reduction of nuclear weapons. Sakharov didn't really need any convincing, but he gave von Hippel a hard time, questioning him on details of his model of the use of nuclear weapons and his numbers on casualties during a nuclear war. Sakharov expressed some interesting ideas about acceptable damage and similar topics, showing his technocratic side. Again, he was very clear on the point that SDI wasn't worth the hype that surrounded it. The KGB transcript was sent to Gorbachev, who read it and made notes. Since Gorbachev had few opportunities to learn about issues connected with nuclear weapons and SDI, Sakharov's remarks made an important contribution to his education.

Sakharov spoke about SDI and the reduction of nuclear weapons at the Moscow Forum and his voice carried weight. I don't think Sakharov singlehandedly persuaded Russia to drop their insistence on linkage, but his contributions to the debate were important. Sakharov recognized early on that missile defense is a problem, it's not a solution. The effect of missile defense is that it disrupts stability and order, and it prevents real steps toward complete nuclear disarmament, which Sakharov believed was the real goal and a necessity. We should step back, consider Sakharov's attitude toward missile defense, and apply it to the current situation.

Paul Doty

The panel has used up its time, but if there is a question or two, let's have them.

Question

How would development of thermonuclear energy affect concerns about the safe use of nuclear energy? Which steps to make nuclear energy safer and which mechanisms already in place to keep nuclear energy safe would still be applicable and important? What new issues might arise?

Matt Bunn

I think that fusion has for so long been "fifty years away" that analyses of those subjects are at a much more primitive stage than they are for the nuclear power that here's today. There were some fairly detailed analyses done jointly by U.S., Soviet, and European scientists, including Wolf Hafele and EvgenyVelikhov, comparing a thermonuclear-fueled future versus a future fueled by fission breeders and plutonium. I think that fusion would bring a lot of advantages over fission on the safety front, the nuclear waste front, the terrorist front, and the proliferation front. But of course fusion, like fission, is a potential source of neutrons, so a country that wanted to use a fusion plant to produce plutonium would probably find a way to do that. However, it would probably be easy to design a fusion plant so that it couldn't do that without it being obvious and requiring some significant modifications to the facility.

While comparative analyses have not been done at the level of detail that one would like, my guess is that fusion would ultimately have quite a few advantages, but there are a lot of

technological and economic challenges before we get a world powered by thermonuclear energy. When that time comes, I guess we would adapt the existing international organizations to inspect and regulate thermonuclear power plants.

Question
There is a type of nuclear peril that was ignored: if you want to build -- as we need to – fission reactors, they don't exist on the market. You all speak as if you could get them off the shelf. But the actual situation is very traumatic. There are two reactors that you could, let's say, order. One is the AP 1000 from Westinghouse, but the first prototype has yet to be built. The other one is from AREVA in France, and it's called the EPR, which they are barely building. If you need a pressure vessel, there is only one company in the world, in Japan, that can produce it. We have to remedy the lack of capacity to build nuclear power stations since we need them.

Matthew Bunn
It is a bottleneck, although there are actually four major companies that you can get modern nuclear reactors from, not just two: there are the Russians after all. But all of the major companies have constraints on their capacity. There's no way we can get twenty-five reactors annually in the next few years. That would mean building forty or fifty reactors a year as we approach the end of the period if we want to reach the target I mentioned in my talk -- producing 1100 gigawatts of nuclear energy by the year 2050. There are companies getting ready to compete with Japan Steel Works in making pressure vessels, but it will take time.

There's the people issue as well, not just the pressure vessels bottleneck. Many people in the nuclear industry are about to retire, or are already retired, and the new generation coming along is much smaller. They won't be enough either for a growing nuclear energy enterprise or a growing disarmament enterprise. More than half of the inspectors at the International Atomic Energy Agency will reach mandatory retirement age in the next five years. It's a crisis. We don't have the nuclear inspectors we are going to need to carry out the kinds of measures that are required for the nuclear future we'd all like to have.

Question
When you think of the cost of nuclear reactors, based on the French experience of spending $4,000,000,000 on each one, it seems to me that if we were to build six, eight or ten a year to meet our energy demands, it would be cheaper, safer, better from all points of view to put those billions of dollars into solar, wind, and wave energy, which are decentralized and not subject to threats of terrorism. Senator McCain talked about building forty-five reactors in the United States and Rosatom wants to build one hundred reactors, all by 2030; this amounts to hundreds

of billions of dollars. One last comment. There is one other state that generates more than half of its energy from nuclear power and that's Vermont.

Matthew Bunn
The climate challenge is so big and daunting to a world that is 85 percent dependent on fossil fuels that we're going to need every technology we have available. We cannot yet rule out any of the things we have available. We need to work as hard as we can on efficiency, on solar, on wind – and on nuclear power.

Frantisek Janouch
The net increase in the global population is about 250,000 persons a day. If the average per capita daily consumption of electricity is two kilowatts, we need to build an additional 1,000 megawatts of production capacity every second day for supply to keep up with population growth. I cannot imagine that you can get this amount of energy from wind power. Also keep in mind that at the present time, 80 percent of the energy produced is used by 20 percent of the world's population. The other 80 percent of the world's population will almost certainly increase their future per capita energy use.

Paul Doty
We haven't exhausted Sakharov's nuclear legacy but we have exhausted our time.