PROGRAM ON SCIENCE AND GLOBAL SECURITY

Woodrow Wilson School of Public and International Affairs
Princeton University

Annual Report for 2013
(January 1, 2013 – December 31, 2013)

Bruce G. Blair, Christopher F. Chyba, Harold A. Feiveson, Alexander Glaser, Laura H. Kahn, Zia Mian, Seyed Hossein Mousavian, M.V. Ramana, and Frank N. von Hippel
# TABLE OF CONTENTS

I. Introduction and Summary
   1

II. Research and Policy Analysis
   3

   Controlling and Eliminating Fissile Materials
       3
   The International Panel on Fissile Materials – informing the debate
   Dry cask storage as an alternative to reprocessing spent nuclear fuel
   Plutonium disposal
   A fissile material strategy for the Middle East
   Ending the use of HEU as reactor fuel
   Naval fuel cycle

   The Future of Nuclear Power
       8
   Responding to Fukushima
   Characterizing nuclear power in models for energy policy-making
   Nuclear energy in Saudi Arabia
   Small modular reactors
   Thorium-based reactors
   Spent fuel management
   Slowing the spread of uranium enrichment facilities

   Nuclear Arms Control and Disarmament
       12
   Nuclear archeology
   Warhead verification
   Arms control and disarmament policy

   Addressing Iran’s Nuclear Program
       15
   *Unmaking the Bomb, a Book on Fissile Material Control*
       16

   Nuclear Threat Reduction in South Asia
       16
   Nuclear weapons in South Asia
   Nuclear energy in South Asia

   Strengthening Biological Security
       20
   One Health and Antibiotic Resistance
   Biosecurity

   Robotic Weapons
       22

   Space Security
       23
III. Fostering the Development of Independent Technical Expertise and Training

A Worldwide Network
IPFM website and blog
Science & Global Security
Teaching and Mentoring

APPENDICES

A. Personnel
B. Publications and Reports
C. Lectures, Talks, Workshops
D. Program on Science and Global Security Weekly Seminars
E. Sources of Funding
I. Introduction and Summary

Princeton University’s Program on Science and Global Security (SGS), within the Woodrow Wilson School of Public and International Affairs, continues to impact national and international nuclear, space, and biosecurity policy through its research and analysis and by fostering an international network of independent science and security researchers working on these issues.

Research and Policy Analysis

During the past year, members of SGS contributed in the following areas:

- Reducing the dangers posed by nuclear weapons, fissile materials, and nuclear energy;
- Minimizing nuclear threats in South Asia;
- Strengthening biological security with respect to antimicrobial resistance, natural disease, and dual-use biotechnology;
- Assessing robotic weapons; and
- Furthering space policy and security.

Much of SGS’ research on nuclear dangers relates to its role as the research and administrative arm of the International Panel on Fissile Materials (IPFM), a group of independent nuclear experts from 17 nuclear-weapon and non-weapon states. The IPFM’s mission is to educate interested governments and the public on the technical basis for policy initiatives to secure, consolidate, and reduce stockpiles of highly enriched uranium and plutonium.

One major focus of our work on nuclear issues during 2013 was on the disposition of spent nuclear fuel. We also continued to study the proliferation resistance of so-called Small Modular Reactors (SMRs) – proposed reactor designs with electrical power outputs less than 300 MWe. And we continued an effort to outline the basis for a diplomatic solution to the confrontation over Iran’s uranium enrichment program. Finally, we completed and submitted to MIT Press for publication in 2014 a nearly final draft of a book, *Unmaking the Bomb*, which provides an introduction to and overview of fissile material issues.

Our work on South Asia is to inform nuclear policy debates in India and Pakistan and to inform international policy towards these countries’ nuclear programs. Our central goal continues to be to explore the basis for measures that could slow and stop the arms race between India and Pakistan.

In our work on biosecurity, we have continued to stress the importance of increased communication and collaboration between physicians, veterinarians, and other public health officials in addressing zoonotic (animal-origin) diseases that can cross over to humans. We have especially focused on the rise of antibiotic resistance. We have also continued to explore ways to minimize the potential threat arising from the misapplication of advances in biotechnology.
Research on robotic arms control has examined the basis for a ban on autonomous weapons. Research on space security focuses on space debris and environmental protection, missile defense and anti-satellite weapons, and their relationship to strategic stability.

**Fostering a Community of Independent Technical Security Experts**

SGS provides education and training opportunities for Princeton undergraduate and graduate students, as well as post-doctoral and senior academics who are interested in science and security. The international network that has resulted over the years has allowed us to contribute more effectively to the international nuclear policy debate and to the national nuclear policy debates of a number of countries. SGS is also the editorial home for *Science & Global Security*, the international journal of arms-control science.

During 2013, SGS hosted seven research collaborators:

- **Ali Ahmad** (Postdoctoral Research Associate), a graduate of the Lebanese University in Beirut, holds a PhD in nuclear engineering from Cambridge University. His work addresses fuel cycle assessments, nuclear energy and climate change, small modular reactors and the introduction of nuclear power to new markets.

- **Shoib Chakravarty** (Postdoctoral Research Associate) holds a PhD in physics from Princeton and is now at India’s National Institute of Advanced Studies in Bangalore. In summer 2013, he worked at SGS on better ways of incorporating nuclear power into integrated assessment models.

- **Mark Gubrud** (Postdoctoral Research Associate) was with SGS through October 2013. He is a physicist who has been active in the International Committee for Robot Arms Control and is also known for his participation in the space security debate.

- **Pervez Hoodbhoy** (Visiting Research Collaborator) who retired in 2010 as Chair of the Department of Physics at Quaid-i-Azam University in Islamabad, Pakistan, is a long-time collaborator with Mian in efforts to educate the Pakistani public on the dangers of nuclear weapons.

- **R. Scott Kemp** (Visiting Research Collaborator) works on technology change and the future of nuclear proliferation. He is Assistant Professor of Nuclear Science and Engineering at the Massachusetts Institute of Technology. He spent summer 2013 with SGS.

- **A.H. Nayyar** (Visiting Research Collaborator) retired in 2005 from the Department of Physics at Quaid-i-Azam University in Islamabad and until recently was a Professor in the Department of Physics at Lahore University of Management Sciences. He has been a regular summer visitor with the South Asia Project since 1998.

- **Wang Ting** (Postdoctoral Research Associate) holds a PhD from Beijing University of Aeronautics and Astronautics, and joined SGS in September 2013. He is working on space debris problems, missile defense and anti-satellite weapons, and their relationship to strategic stability.
SGS faculty and researchers teach science and security courses and policy workshops for Princeton undergraduate and graduate students.

*Science & Global Security* is edited by Glaser, Mian, and Pavel Podvig. It has become an essential institution in the field of science-based security studies. It is published in Russian as well as in English, with occasional articles translated into Chinese.

**The SGS Research Group**

SGS is directed by Christopher Chyba. Harold Feiveson and Frank von Hippel, who together co-directed the Program from 1974 to 2006, retired from teaching in 2013 but continue their research as members of the Program. The SGS faculty and research staff also includes: Alexander Glaser, who focuses on nuclear-reactor, fuel-cycle, and warhead verification issues; Laura Kahn, MD, who works on policy relating to protection of the public against natural and human-caused disease outbreaks; Zia Mian, who directs the Program’s Project on Peace and Security in South Asia; M.V. Ramana, who works on issues related to the future of nuclear energy in developing countries; and Pavel Podvig, located in Geneva, who manages the IPFM blog. Bruce G. Blair, founder of Global Zero, joined SGS in 2013 as a research scholar. Rob Goldston, former director of the Princeton Plasma Physics Laboratory, is affiliated faculty with the Program and collaborates on both fusion power and warhead verification issues.
II. Research and Policy Analysis

Controlling and Eliminating Fissile Materials

During 2013, our work relating to the reduction of the dangers associated with fissile materials focused on:

- Global promotion of dry cask storage as an alternative to the separation of plutonium from spent fuel;
- Plutonium disposal in the United States;
- A fissile material strategy for the Middle East;
- Accelerating the phase out of the use of HEU fuel in Russia’s research reactors; and
- The naval reactor fuel cycle.

Much of our work in this area involves the International Panel on Fissile Materials for which the Program provides the research and administrative base.

The International Panel on Fissile Materials – informing the debate

The IPFM was established in January 2006 with a five-year grant from the MacArthur Foundation. In 2011, it received grants for an additional three years of work from the MacArthur Foundation with additional support from the Carnegie Corporation.

The IPFM has members from eighteen countries. During 2013, two new members joined: Gordon MacKerron, Director of the University of Sussex Science Policy Research Unit and founding chair of the UK government's independent Committee on Radioactive Waste Management (2003-7); and Paul Meyer, formerly Canada’s Ambassador to the Conference on Disarmament (2003-7). James Acton left the Panel.

In March 2013 the panel held its annual meeting in London hosted by Chatham House. The main subjects were weapon-state transparency and plutonium disposition. IPFM experts presented their perspectives and recommendations and heard presentations from officials from the UK Foreign and Commonwealth Office on transparency and from the Department of Energy and Climate Change and the UK Nuclear Decommissioning Authority on plutonium disposition.

In addition to an annual update on global stocks, production and elimination of fissile materials by Alex Glaser and Zia Mian, the IPFM Global Fissile Material Report 2013 provided a comprehensive set of proposals on nuclear weapons and fissile materials transparency supported by chapters on:

- “Nuclear Weapon State Transparency, the Nuclear Non-Proliferation Treaty and the United Nations,” by Randy Rydall, UN Office of Disarmament Affairs;
- “Nuclear Warhead Stockpiles and Transparency,” by Hans Kristensen, Federation of American Scientists;
• “The International Plutonium Guidelines,” by Fred McGoldrick, U.S. State Dept., retired; and
• “Nuclear Archaeology and Warhead Verification Collaborations,” by James Fuller, U.S. National Nuclear Security Administration, retired.

From October 2012 to October 2013, the IPFM website registered more than 23,000 visitors (about 14,000 unique visitors) accessing about 60,000 pages. About 40% of the visitors were from the United States. The other countries in the top ten list were Japan, the Netherlands, India, the United Kingdom, China, France, Canada, Germany, and Switzerland. It appears that the site is being used as a professional resource by universities; the International Atomic Energy Agency; and the U.S. Department of Energy and its laboratories; the Department of State; Nuclear Regulatory Commission; Department of Defense; Congressional Government Accountability Office; the Senate and House of Representatives; France’s Commissariat a L’Energie Atomique and AREVA; and the United Nations.

Dry cask storage as an alternative to reprocessing spent nuclear fuel

SGS is leading a project to inform the policy debates in the countries that still reprocess (China, France, India, Japan, Russia and the UK) plus South Korea, which is asserting its right to reprocess.

During 2013, we partnered with the Asahi Shimbun in informing Japan’s policy debate. In August 2013, the newspaper reported on IPFM’s proposed “roadmap” for Japan out of reprocessing and posted an overview in both English and Japanese on its website prior to the publication of the IPFM report, Ending Reprocessing in Japan: An Alternative Approach to Managing Japan’s Spent Nuclear Fuel and Separated Plutonium. On 5 December 2013, the Asahi Shimbun hosted an afternoon of debate in Asahi Hall on “Managing Spent Fuel: To Reprocess or Store?” with six foreign participants recruited by SGS. This group also briefed groups of members of the Diet and gave press and interviews about the dangers of reprocessing and the cost and safety advantages of dry-cask spent-fuel storage.


In China, on 2 December 2013, von Hippel gave a talk at Tsinghua University, Beijing on how badly reprocessing has turned out for Japan. We have been sharing our perspective with a senior official in China National Nuclear Corporation (CNNC) and are gratified to learn

3 Steve Fetter, recently Assistant Director at Large in the White House Office of Science and Technology Policy; Klaus Janberg, former Managing Director of the German company GNS, which developed and produced the first interim storage casks for spent fuel; Allison MacFarlane, Chairman, Nuclear Regulatory Commission; Gordon Thompson, Institute for Resource and Security Studies; Frank von Hippel and William Walker, St. Andrews University, Scotland.
that the CNNC appears to be backing away from buying a reprocessing plant from France’s AREVA and breeder reactors from Russia’s RosAtom.

In France, in March 2013, a group of experts organized by the SGS project had meetings in Paris with government officials and gave presentations on the economic and nonproliferation reasons that favor dry-cask storage over the reprocessing of spent fuel. This perspective is clearly shared by France’s national utility, Électricité de France, which is required to support AREVA at home but has refused to support reprocessing in the U.K., where it has bought almost all the nuclear power plants.

India’s National Science Academy published a book, India's Nuclear Energy Programme edited by the IPFM’s R. Rajaraman including a chapter by von Hippel critiquing India’s reprocessing program.  

IPFM’s Anatoli Diakov published an article in Science and Global Security on the evolution in Russia of thinking about reprocessing. Rosatom is investing heavily in fuel cycle and breeder reactor R&D but is becoming more sensitive to economic considerations and continues to delay any commitment to building a commercial-scale reprocessing plant or breeder reactors.

IPFM’s Jungmin Kang and two social scientists colleagues have received funding from the MacArthur Foundation to organize “town meetings” in the host communities of each of South Korea’s nuclear power plants on safety advantages of dry cask storage of spent fuel. Kang will provide the briefings and the social scientists will analyze questionnaires on the attitudes of the participants before and after the briefings.

Plutonium disposal

In spring 2013, the Obama Administration announced that the current program of converting excess U.S. weapons plutonium into mixed-oxide (MOX) fuel for U.S. power reactors was becoming “unaffordable”. Von Hippel and two colleagues wrote an article laying out the alternatives that has been an important source of information for the Administration’s analysis.

A fissile material strategy for the Middle East

In October 2013, we produced an IPFM report on Fissile Material Controls in the Middle East: Steps toward a Middle East Zone Free of Nuclear Weapons and all other Weapons of

---

4 Presentations by Klaus Janberg, Gordon MacKerron, Mycle Schneider and Frank von Hippel at the Paris-based Fondation pour le Progrès de l’Homme.
There has been a surprising amount of interest in this work. The preliminary findings were presented at the 2013 meeting of the Preparatory Committee for the 2015 NPT Review Conference and the final report has been presented at the 2013 meetings of the UN’s First Committee on Disarmament and International Security; the Annual Conference of Arab Institute for Security Studies, Amman, Jordan; and at seminars and workshops in Doha and in Jerusalem.

One of the proposals made in the report is that national enrichment plants be put under multinational control. At the end of October 2013 the Program co-organized with Georgetown University in Doha a workshop that included a session on multinational arrangements for enrichment including presentations by Gregoire Mallard and Christopher Paine on different possible international overlays over national enrichment plants and Sir John Thomson on the possibility of URENCO taking over Iran’s enrichment complex.

**Ending the use of HEU as reactor fuel**

Highly enriched uranium (HEU) is of particular concern with regard to the possibility of nuclear terrorism because it is much easier to make a nuclear weapon from HEU than plutonium. During the “Atoms for Peace” era in the 1950s and 1960s, however, the United States and Soviet Union each built scores of HEU-fueled research reactors at home and exported such reactors to more than 40 countries.

Russia has been cooperating with the U.S. Global Threat Reduction Initiative in converting HEU-fueled reactors in third countries and in repatriating fresh and spent HEU fuel exported by the Soviet Union and Russia. Until recently, Russia has not given as high a priority to converting its own HEU-fueled research reactors or shutting down obsolete research reactors. It still has about 50 HEU-fueled research reactors and critical assemblies vs. 15 each in the United States and the EU and 23 in the rest of the world. In September 2013, in partnership with the IAEA’s Department of Nuclear Energy and with funding from the MacArthur Foundation, Pavel Podvig organized a successful workshop at the IAEA’s headquarters in Vienna on “International cooperation on minimizing the use of HEU in research” with experts primarily from Russia and the U.S. government. An IPFM report with papers from that workshop is in preparation.

Our past efforts in this area bore fruit during 2013 at the Institute of Physics and Power Engineering (IPPE) in Obninsk, where Gennadi Pshakin and his colleagues have initiated the blend-down of a ton of lightly irradiated HEU and 660 kg of weapon-grade HEU in

---


thousands of disks used in the world’s largest fast-neutron critical assemblies. We have been working with Pshakin on these initiatives for almost a decade.

**Naval fuel cycle**

At our suggestion, the House Armed Services Committee requested that the Department of Energy’s Naval Reactor Program revisit the possibility of designing future naval reactors to be fueled with LEU. The report is overdue but the staffer that put in the request has been told that it is complete and less negative than the 1995 report.

At this point, the fueling of the next generation of naval reactors with weapon-grade uranium appears to be locked in: the *Virginia*-class attack submarines are in serial production; the first *Ford*-class aircraft carrier is nearing completion; and the design of the reactor for the ballistic missile submarines that are to replace the *Ohio*-class is well underway. On the other hand, with no other new designs in prospect for some time, this would be a good time to launch conceptual studies on LEU-fueled reactors. We understand that the draft report indicates that the Office of Naval Reactors is open to this idea if funding support were made available.

Brazil currently is engaged in developing nuclear submarines – the first non-nuclear weapon state to do so. Two of our students have written papers relating to this effort: Andrea da Sa did her senior thesis on Brazil’s nuclear program, including many interviews in Brazil and research in associated archives. She has completed and submitted to *Nonproliferation Review* a paper laying out the history of the program and the proliferation issues. Fortunately, Brazil is currently focusing on LEU fuel.

As a result of discussions with de Sa, the former deputy manager of Brazil’s naval reactor program has arranged the hosting of the next IPFM annual meeting in March 2014 in Rio de Janeiro.

After taking the class "Protection against Weapons of Mass Destruction" taught by von Hippel and Mian in the spring, one of our PhD students, Sébastien Philippe, expanded his class final paper into an article proposing methods by which the IAEA could verify the non-diversion of enriched uranium from Brazil’s naval fuel cycle, which he has submitted to the *Journal of Nuclear Materials Management*.

**The Future of Nuclear Power**

Though prospects for a worldwide expansion of nuclear power have diminished following the March 2011 nuclear accident in Fukushima, Japan, some countries continue to construct nuclear reactors (most notably China and India) and a number of countries are proceeding with plans to acquire their first nuclear power plants. Nuclear power advocates in these and other countries increasingly cite the lower carbon dioxide emissions from nuclear power compared to fossil fuels as a major benefit of this technology. Over the past year, SGS researchers continued to explore the potential growth of nuclear power, the scope for new reactor technologies, and issues of economics, safety and nuclear-weapon proliferation.

---

**Responding to Fukushima**

The Fukushima accident led to a worldwide questioning of the current reliance on nuclear energy. M. V. Ramana examined and characterized the range of national responses around the world in a widely read article in the *Bulletin of the Atomic Scientists*. Broadly speaking, these responses fall into three categories: Within one group, countries have decided to turn away from nuclear power, either through a gradual phase-out or by abandoning plans for programs that had not yet begun. In the second group of countries, government leaders who were otherwise inclined to continue pursuing nuclear power were forced by protests and public opinion to change their policies. And in the third group, countries have reiterated their commitment to nuclear power. Ramana also identified several common elements that seem to be at play in countries that are staying the course on nuclear power, including: hasty dismissals by government officials of the Fukushima accident’s applicability to their own countries, affirmations of the safety of deployed or proposed reactor designs, propaganda campaigns supporting nuclear energy, reliance on international financing for reactor construction, and an emphasis on the need to meet projected growth in energy demand. Ramana presented this work as part of an overview of global developments in nuclear energy at the October 2013 SGS-Georgetown University School of Foreign Service workshop in Doha on “Nuclear Technology, Nuclear Energy and a Middle East WMD-free Zone.”

**Characterizing nuclear power in models for energy policy-making**

A major argument being advanced for increasing reliance on nuclear energy is the need to reduce greenhouse gas emissions associated with electricity production. Alex Glaser and Ramana have been working with Shoibal Chakravarty, a post-doctoral visitor with the Program over the summer now based in India, to examine how nuclear power could be better captured in the integrated assessment models that combine detailed models of economy, energy and climate to project the climate implications of possible energy policies.

In mapping out a lowest-cost energy mix for reducing greenhouse gas emissions, integrated assessment models often project a need for a large fraction of nuclear power—in part because of the assumption that nuclear energy offers lower cost electricity than renewables. These models implicitly ignore the possibility of severe nuclear accidents and consequences for energy policies. As the experience of Fukushima has shown, when nuclear accidents occur they have significant costs of cleanup and possible deployment: the costs of cleanup at Fukushima are estimated to be around $100 billion and Japan has thus far not resumed operating any of its 50 nuclear power reactors. Chakravarty, Glaser and Ramana have adopted a dynamic programming approach to model the likely deployment of nuclear power over the next few decades including the risk and consequences of accidents. Their preliminary results show that if the probability of a severe accident is one in 100,000 reactor years or higher, the worldwide deployment of nuclear power would be reduced significantly by the end of the century. Theoretical estimates of the probability of a severe accident in the latest generation of reactors tend to be lower than once in a million years whereas the empirical record of accidents so far suggests a probability of greater than once in ten

---

thousand years.

**Nuclear Energy in Saudi Arabia**

One country that continues to be interested in acquiring nuclear reactors is Saudi Arabia, which has announced plans to embark on an ambitious program to install 18 GWe of nuclear capacity within the next two decades to meet projected needs for electricity and water desalination. Ramana and new SGS post-doc Ali Ahmad examined the economics of nuclear power in Saudi Arabia and compared it to other sources of energy both for electricity generation and water desalination. They found that for Saudi Arabia the economics of nuclear power are not favorable in comparison with natural gas, even if the currently low domestic natural gas prices in Saudi Arabia were to rise substantially. They found also that electricity from solar plants has the potential to be cheaper than nuclear power within the next decade if the rapid decline in solar energy costs in the last decade continue, i.e., before the first planned nuclear power plant would be completed. Ahmad presented this work at the Doha SGS-Georgetown University workshop and it stimulated much discussion. A paper based on this work has been submitted to *Energy*.\(^{12}\)

In light of Iran’s nuclear program, Saudi Arabia’s interest in nuclear energy has raised concern about possible proliferation in the Middle East. In an article for the *Bulletin of the Atomic Scientists*, Ahmad reviewed the Saudi public debate and concluded that the international community should take seriously Saudi leadership arguments about acquiring a nuclear weapon if Iran succeeds in developing one or even getting international recognition of its nuclear program.\(^ {13}\) The planned nuclear power program may not make economic sense as an energy option, but would seem to be the most plausible route to a Saudi nuclear weapon capability.

**Small modular reactors**

Alex Glaser and Ramana continued to examine technical and policy challenges related to small modular reactors (SMRs), i.e., reactors with power outputs of less than 300 MWe. These have been suggested as an alternative to the costly 1000-1600 MWe reactors that are currently being offered by the international nuclear industry vendors. In a paper published in *Energy*, Ramana and Glaser along with Laura Berzak Hopkins, a former member of SGS, examined one of the important challenges confronting the adoption of SMRs: to have these new reactor designs licensed by national regulatory bodies.\(^ {14}\) Because of the many novel features incorporated in different SMR designs, careful and thorough licensing procedures are critical to maintaining safety of the nuclear fleet. Ramana and Glaser observed that in many cases SMR designers have argued that their reactor designs have incorporated so many safety features—for example, constructing reactors underground and incorporating steam generators inside the reactor pressure vessel—that regulatory authorities should permit existing licensing requirements for nuclear reactors to be eased. One particular focus has

---


been to allow reactors to be deployed without a sizeable zone where emergency plans for evacuating or otherwise dealing with a severe accident are put in place. This raises the concern that the safety enhancements promised in SMR designs could be offset by a simultaneous relaxation of licensing requirements leading to an overall higher risk or impacts of severe accidents to the populations living in the vicinity of reactors.

Small modular reactors were also one focus of discussion at the Doha SGS-Georgetown University workshop and Glaser presented an overview of different SMRs that are being developed. These designs vary by power output, physical size, fuel geometry, fuel type and enrichment level, refueling frequency, spent fuel isotopic composition, deployment location, and status of development. Glaser has proposed classifying SMR designs into four families. The first family involves reactor designs that are essentially standard but scaled-down light water reactors, and these are likely to be first to be commercialized. A second family consists of high temperature gas-cooled reactors, which promise greater safety because of their use of special fuel types; these are often viewed as a source of both electricity and process heat for industrial purposes. A third family of reactors attempts to deal with the legacy of accumulated nuclear waste, by using it as fuel, thereby reducing demand for uranium. Lastly, there are designs with long-lived cores that are designed for possibly unattended operation, which are generally targeted at “newcomer” nations with small electric grids interested in developing nuclear power systems or remote locations in developed countries. These different reactor types exhibit characteristic advantageous and disadvantageous technical features when evaluated against criteria such as safety, non-proliferation, economics, and waste generation.

Last summer, Ramana spent ten days in China interacting with reactor designers and researchers involved in developing the High Temperature Reactor that is being constructed in Shandong province. The focus of his discussions was on how designers envisioned the safety of this SMR design and its vulnerability to different classes of accidents. Ramana also attended the International Conference on Nuclear Energy in Chengdu, where he presented a paper on resource requirements and proliferation risks of SMRs and chaired two separate sessions, both of which dealt with new reactor designs.

**Thorium-based reactors**

One potential class of small modular reactor designs involve the use of thorium in addition to uranium as fuel, because the former is much more abundant than the latter. Last year, Alex Glaser supervised a Senior Thesis by Edward McClamrock (MAE, Class of 2013) on one class of thorium reactors that are called Molten Salt Reactors (MSRs). Based on this research, McClamrock and Glaser presented a paper at the 2013 INMM Annual Meeting examining resource requirements and proliferation risks of denatured molten salt reactors. These reactors use fuel that contains depleted uranium, which is added to ensure that the uranium recovered from the reactor after use would not be weapons-grade. This fuel is in the form of a molten salt that is never chemically processed. Ahmad and Glaser have recently further refined this analysis and will be submitting the results for publication.

The analysis confirms that MSRs could offer significant advantages with regard to their requirement for uranium compared to conventional thermal reactors based on light-water reactor technology. Depending on specific design choices, MSRs could reduce uranium and
enrichment requirements by a factor of 3–4. Nonetheless, the near-term demonstration of a prototype MSR faces significant obstacles, and many technical challenges—for example, the corrosion of the structural materials used in the reactor vessel and heat exchangers by the molten salts—have to be resolved. Specific design choices for molten salt reactors have important implications for associated proliferation risks and it is critical to keep nonproliferation criteria in mind from the outset when narrowing technology choices for MSRs.

**Spent fuel management**

In addition to the risk of proliferation, another challenge that confronts an expansion of nuclear power is dealing with spent nuclear fuel and high-level radioactive waste. Over the decades, the experience of many countries trying to develop methods for dealing with these and identifying locations to site repositories has highlighted the importance of the social and political factors in addition to technical criteria. In a paper published in *Energy Policy*, Ramana extended his earlier work performed as part of the 2011 IPFM report on spent fuel management to examine the progress in Canada’s efforts to identify a site for a geological repository to sequester nuclear waste. Although the Canadian Nuclear Waste Management Organization (NWMO) laid out a set of principles to foster a participatory process to select a community to host such a repository, Ramana observed that differences had cropped up between the broad principles and the actual selection process, from lofty themes of inter-generational equity and fairness in siting to altogether more down-to-earth details about numbers of jobs and additions to the tax base.

**Slowing the spread of uranium enrichment facilities**

Scott Kemp, now at MIT, spent his summer with SGS working on a new approach for assuring the availability of stocks of enriched uranium nuclear fuel for nuclear power plants as an alternative to the proliferation of enrichment facilities and as a complement to foreign fuel banks, which stockpile relatively small quantities of LEU and not fabricated fuel. The proposal, based loosely on existing global requirements for national strategic oil reserves, could have economic implications for utilities required to hold stockpiles of fabricated fuel and for commercial enrichers. In order to understand these implications, Kemp built an economic model of the enrichment markets. He is extending this work at MIT with a game-theory study of competition.

**Nuclear Arms Control and Disarmament**

**Nuclear archaeology**

Nuclear archaeology uses nuclear-forensic analysis of samples of structural or waste materials from nuclear production facilities to obtain evidence relating to their operating history. To date, the best-established example of nuclear archaeology is the use of measurements of isotope ratios of selected trace elements in the graphite of graphite-

---

moderated plutonium production reactors to determine how many neutrons passed through the graphite and thereby how much plutonium the reactors have produced. Pioneering work in this area has been done at PNNL. We have previously extended the concept to heavy water reactors.\textsuperscript{16}

With regard to HEU, there are a few ideas for how to independently assess historic production of highly enriched uranium using signatures from the equipment or waste material associated with the enrichment process. We have explored one such strategy in a recent article, based on research undertaken by Sébastien Philippe, PhD student at MAE.\textsuperscript{17} We plan to continue and expand our conceptual work in the area of nuclear archaeology over the next few years.

\textit{Nuclear warhead verification}

Since 2012, Glaser has been working a nuclear warhead verification project in collaboration with Global Zero (www.globalzero.org) and Princeton's Plasma Physics Laboratory. The project is also supported by a grant from the U.S. Department of State’s Bureau of Arms Control, Verification and Compliance (AVC). The main objective of this research is to develop and demonstrate a viable verification approach that resolves the tension between verifying that an inspected warhead is authentic while protecting classified design information.\textsuperscript{18} This capability is needed because the next round of nuclear arms-control agreements may limit tactical and non-deployed weapons, which would then require accounting for individual nuclear warheads.

The project team has so far analyzed the approach using computer simulations. An experimental facility to support this research is currently being set up at Princeton’s Plasma Physics Laboratory and, in December 2013, we performed first trial exposures of dedicated neutron detectors. In addition to Glaser, Philippe, and Mark Walker, this research will also involve a new post-doc (Yan Jie) from China’s Academy of Engineering Physics.

\textit{Arms control and disarmament policy}

Bruce Blair, a co-founder of the Global Zero international movement for the elimination of nuclear weapons, joined the Program in 2013, where he works in the arena of nuclear arms control. In testimony before Congress on the evolving requirements of U.S. nuclear force structure and posture, Blair outlined steps toward reducing the scale and costs of nuclear programs, including recommendations to negotiate deep cuts in nuclear stockpiles, phase out land-based strategic missiles, and take deployed missiles off launch-ready alert.\textsuperscript{19} His recommendations drew substantially on a 2012 study he directed under a high-level


\textsuperscript{19} U.S. Congress, House Committee on Armed Services, Subcommittee on Strategic Forces, "The U.S. Nuclear Deterrent: What are the Requirements for a Strong Deterrent in an Era of Defense Sequester?," 19 March 2013.
commission led by Gen. (ret.) James Cartwright and former Senator Chuck Hagel (now Secretary of Defense) and on a Russian study conducted in response to the Cartwright-Hagel report authored by retired Russian generals.  

The current impasse with Russia over re-starting bilateral negotiations on nuclear arms reductions reflects serious differences over missile defense and conventional arms imbalances. President Putin rebuffed President Obama’s overture to reduce deployed strategic weapons by one-third below current new START limits. As a member of Secretary of State John Kerry’s International Security Advisory Board (ISAB), Blair is developing proposals for the State Department to consider in its efforts to chart a new approach to U.S.-Russian nuclear security cooperation. Blair’s previous ISAB efforts to identify a promising path forward in nuclear arms control resulted in a report published by the State Department in late 2012.  

The path to the total elimination of nuclear weapons will require multilateral cooperation among all nations that possess them. As multilateral reductions lead to lower and lower numbers of total weapons, an important question arises: can multipolar stability be maintained at very low numbers in light of possible coalitions, varying conventional and missile defense capabilities, and other factors such as reduced alert levels? Building upon previous collaborative work on bipolar stability at low numbers, Blair will collaborate to examine through modeling and simulation the prospect of achieving multipolar stability at low numbers. As part of this work, Blair is collaborating with Mathew McKinzie and Hans Kristensen in preparing tabletop exercises to assess the propensity of de-alerted nuclear postures to begin re-alerting in a crisis. Critics of de-alerting argue that it invites an unstable re-alerting race.

The conventional forces dimension of stability is no less important, and therefore Blair is calculating the lethality of U.S. conventional weapons in operations against a spectrum of strategic targets including hardened missile silos. These calculations will help gauge the potential for conventional arms to de-stabilize nuclear balances, test the validity of other countries’ assessment of these capabilities and their de-stabilizing effects, and assess the scope for replacing U.S. nuclear weapons with conventional weapons.

Blair is building upon his previous work on withdrawing tactical nuclear weapons from Europe by teaming with Ivo Daalder, the former U.S. Ambassador to NATO. Blair and Daalder are assembling a high-level track 2.0 commission co-chaired by former Secretary of

---

State Madeleine Albright and former U.K. Foreign Secretary Malcolm Rifkind to define and evaluate options for eliminating tactical nuclear weapons from Europe. A series of workshops will produce a report to be offered to the October 2014 NATO summit of heads of government hosted by U.K. Prime Minister Cameron.

A path to a nuclear-free world will entail developing new technologies for monitoring and verifying individual nuclear warheads. Blair is collaborating with SGS faculty Glaser and Goldston in this area, and will be contributing policy perspective to the technical work.

Blair mentors international students in the 176 college and high school chapters of Global Zero around the world. He lectures and conducts training during 2-3 student institutes convened annually by Global Zero. Blair is exploring other means of educating students around the world on nuclear arms control, including the possibility of developing a massive open online course on the subject.

Chyba continues to work on issues of nuclear weapons arms control. He remains involved with (though no longer a formal member of) the National Academy of Sciences’ Committee on International Security and Arms Control. Chyba currently serves on President Obama’s Council of Advisors on Science and Technology (PCAST).

Chyba’s PhD student, Caroline Reilly, is addressing issues of nuclear weapons and strategic stability. Reilly’s dissertation is premised on the notion that reciprocal assured retaliatory capabilities create an inescapable condition of mutual vulnerability between nuclear rivals. Regardless of the actions that adversaries may take to address their weaknesses vis-à-vis the other’s nuclear forces, at some point each side should accept the impossibility of breaking out of such a stalemate and instead learn to manage this condition. Her project asks: what is the process by which actors on opposing sides of a nuclear rivalry grapple with the reality of inevitable vulnerability and what is the impact of this process on the prospects for competition, conflict, and cooperation between those adversaries? Reilly first approaches this phenomenon historically by tracing the sequence through which U.S. and Soviet decision-makers perceived and responded to the presence of mutual vulnerability embedded within the strategic force balance during the Cold War. She then compares this case to the more recent confrontation with mutual vulnerability by the United States and the People’s Republic of China in order to illuminate the potential steps that these (and future) nuclear rivals may take to cope with this enduring dilemma in ways most conducive to stability.

**Addressing Iran’s Nuclear Program**

In 2013, Seyed Hossein Mousavian continued his private and public efforts to inform European and U.S. policy makers of the possibilities for a diplomatic solution of the crisis over Iran’s nuclear program and reestablishing normal US-Iran relations. Over the past year, Mousavian also has been advancing ideas for making progress towards a Middle East Nuclear Weapons Free-Zone (ME-NWFZ). This work has been supported by grants from the Ploughshares Fund and Rockefeller Brothers Fund.

Mousavian is uniquely placed for this role, given his background as a member of the staff of Iran’s Supreme National Security Council from 1997 to 2007, including serving as spokesperson for its nuclear-negotiation team during 2003–2005 and serving as Iran’s Ambassador to Germany. Mousavian came to SGS as a visiting fellow in September 2010.
and was appointed Associate Research Scholar in 2011. In 2013, Emad Kiyaei worked as a research assistant on this project with Mousavian, with responsibility for researching, drafting and editing op-eds, scholarly articles and lectures.

Mousavian produced articles, gave lectures and interviews, and participated in discussions trying to inform politicians, policy makers, academics, the media and the general public about the elements of a possible US-Iran rapprochement and possibilities for phased approach to a ME-NWFZ. In his April 2013 article “Globalizing Iran's Fatwa Against Nuclear Weapons,” published in the journal Survival, Mousavian proposed building on the 2005 fatwa (religious decree) by Iran’s leader Ayatollah Ali Khamenei abjuring possession and use of nuclear weapons to create a means for Iran to accept transparency and confidence-building steps by which it could assure the international community that it did not have a secret nuclear weapons program. In September 2013, President Obama cited the fatwa as one of the possible bases for a diplomatic resolution of the nuclear dispute with Iran.24

As part of this work, Mousavian participated in discussions organized by Finland’s government and major international think tanks to assess the prospects for the establishment of a ME-NWFZ. He also co-authored the IPFM research report on Fissile Material Controls in the Middle East.25 This report offers specific recommendations for restraint in uranium enrichment and stockpiles by Iran as part of a series of confidence-building steps that could lead to a nuclear weapons free zone in the Middle East.

Unmaking the Bomb, a Book on Fissile Material Control

During the past year, we completed a nearly final draft of a manuscript for a book to be published by MIT Press in 2014. The working title is Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation. The book is co-authored by Feiveson, Glaser, Mian, and von Hippel. The purpose of the book is to bring together under one cover an overview of fissile material issues and our ideas on how to deal with them. The chapters of the book discuss the:

• Production and uses of nuclear-weapons materials;
• Global stocks of fissile materials;
• Atoms for Peace and plutonium breeder reactor development programs that led to the proliferation of fissile materials and the means of their production;
• Basis for a treaty to end the production of fissile material for weapons;
• Means for detection of clandestine fissile material production;
• Feasibility of ending the use of HEU as a reactor fuel;
• Disposition of excess fissile materials;
• Design of the nuclear fuel cycle so that the spread of civilian nuclear power does not facilitate the spread of nuclear weapons; and the
• Fissile-material dimension of nuclear disarmament.

Nuclear Threat Reduction in South Asia

SGS set up its Project on Peace and Security in South Asia in 1997 to help inform nuclear policy debates in India and Pakistan and to inform international policy towards the nuclear weapons and nuclear energy programs in these countries. The Project is directed by Zia Mian and M.V. Ramana and as part of its activities brings interested South Asian scientists and engineers to Princeton during summers to work on nuclear policy issues.

During the summer of 2013, the Project had two visitors from Pakistan: Professor Pervez Hoodbhoy, who is professor in the Departments of Physics and Mathematics at Forman Christian College University, Lahore, and also teaches in the Physics Department of Quaid-i-Azam University, Islamabad, and Professor A.H. Nayyar, who also has taught at Quaid-i-Azam University and in the Physics Department at the Lahore University of Management Sciences. There was also a short visit by Dr. Suvrat Raju, an Indian physicist, currently at the International Centre for Theoretical Sciences, Bangalore.

The Project and its affiliated researchers have drawn recognition for their work. In 2013, Zia Mian was selected for the 2014 Linus Pauling Legacy Award. Former South Asia Project summer visitor R. Rajaraman, emeritus professor of physics at New Delhi’s Jawaharlal Nehru University, and Ramana were jointly awarded the American Physical Society’s Leo Szilard Award for “outstanding contributions to promote global security issues, through critical analyses of nuclear weapons and nuclear energy programs in India and associated risks in the subcontinent, and efforts to promote peace and nuclear security in South Asia through extensive engagements and writings.” The award will be presented at the annual meeting of the APS in April 2014.

This is the second award from the American Physical Society for researchers affiliated with the Project on Peace and Security in South Asia. The 2010 American Physical Society Joseph Burton Award went to Project visiting researchers Pervez Hoodbhoy and A.H. Nayyar “for broadening the public understanding of science in Pakistan and for informing the public of the dangers of the nuclear arms race in South Asia.”

Nuclear weapons in South Asia

SGS’s South Asia Project has worked since 1997 to understand and explain the dangers created by the nuclear weapons programs and policies of India and Pakistan. Since Pakistan and India tested nuclear weapons in May 1998, there have been recurring crises bordering on war between the two countries and an enduring failure to engage in significant negotiations on arms control measures to restrain their nuclear programs.

For much of the past decade India and Pakistan have been undertaking ambitious nuclear weapons buildups. Pakistan is completing work on its fourth plutonium production reactor and has been testing a range of ballistic and cruise missiles as well as a 60 km range nuclear-capable missile for use on the battlefield. In 2013, India began sea trials of its nuclear submarine, which is intended to carry submarine-launched ballistic missiles and tested its

26 Details can be found in previous annual reports of the Program in Science and Global Security.
newest missile, the 5000 km range Agni-V which may carry three warheads each. The Agni-VI, which India is developing, is reportedly to have a range of over 8000 km and to be able carry up to 10 warheads. These developments have come at little political cost because there are more urgent domestic problems in each country while international concern about the South Asian nuclear arms race has been muted. India is seen as a rising economic power in Asia and the U.S. has interests in having India as an ally to counter the rise of China, while Pakistan’s assistance is seen as vital by the West in supporting the war against Al-Qaeda and the Taliban in Afghanistan and China is emerging as a close security and economic partner of Pakistan.

*Confronting the Bomb: Pakistani and Indian Scientists Speak Out*, a compilation of essays on nuclear dangers in South Asia edited by Hoodbhoy and published by Oxford University Press Pakistan, was released in the United States in early 2013. The volume contains contributions by Hoodbhoy, Mian, Nayyar, Raju, Ramana, Rajaraman and one essay co-authored with Matthew McKinzie of the Natural Resources Defense Council, Washington DC. It has a Foreword by Nobel Laureate John Polyani. An excerpt from Hoodbhoy’s extensive introduction to the book was published in the February 2013 *Bulletin of Atomic Scientists*.²⁸

*Confronting the Bomb* was launched in Washington DC in March 2013 at the Carnegie Endowment for International Peace, at an event featuring Hoodbhoy, Mian and George Perkovich.²⁹ It was also launched by Hoodbhoy and Ramana at a meeting in Berlin sponsored by the Heinrich Böll Foundation in April 2013.

The book has been well received. It was reviewed favorably in 2013 in *Physics Today*, with the reviewer describing it as “an excellent and authoritative primer for the debate about one of today’s main global problems.”³⁰ An article about the book in *The New York Review of Books* noted that “while much has been written about the nuclear bombs of India and Pakistan, there is nothing like the collection of essays entitled *Confronting the Bomb*, by seven Indian and Pakistani scientists.”³¹

In summer 2013, Hoodbhoy worked with Mian and Nayyar to develop ideas and pilot programs for an on-line video series aimed at young people in Pakistan on the use of science and reason to understand nature and society and so better enable citizens to participate in the political, social, economic, and cultural life of their society. This included developing lectures and resource material on: the impact of nuclear weapons on Pakistan; nuclear energy in Pakistan; the energy and water crises in Pakistan; and the challenges of climate change for Pakistan.

In 2013, Nayyar completed work on editing and managing the translation into Urdu of a companion volume of essays on nuclear issues. *Taqat ka Sarab* (The Illusion of Power) has 15 chapters on a range of topics, including the history, evolution and possible future of nuclear programs in South Asia, the command and control of nuclear weapons, issues of safety and security of weapons and the consequences of nuclear war, as well as on the

---

²⁹ http://carnegieendowment.org/2013/03/05/confronting-bomb-pakistani-and-indian-scientists-speak-out/firf
obstacles to disarmament and arms control in the region, and the challenge of nuclear energy in Pakistan and India. It has a lengthy foreword by I. A. Rehman, a distinguished Pakistani journalist. This volume will be the most extensive collection of articles on nuclear issues in Pakistan’s national language. Nayyar and Hoodbhoy plan an extensive series of events in 2014 in Pakistani cities to promote the arguments in the book.

The volume will be published in early 2014 by Mashal books, a non-profit publisher based in Lahore. The book will be also made available for free download on the Mashal website.

**Nuclear energy in South Asia**

In December 2012, Ramana’s book *The Power of Promise: Examining Nuclear Energy in India* was published by Penguin Books, India. The book offers the first detailed history of India’s nuclear energy program, including: the evolution of the goals of India’s nuclear power generation program; its failures to meet these goals; and the economic and social costs, safety risks and environmental consequences that have accompanied it.

The book has received excellent reviews. In the *Economic and Political Weekly*, India’s leading social science and current affairs journal, the reviewer described it as a “seminal book [that] will soon become an essential reference especially for those who are outside the nuclear scientific-industrial network.” The reviewer in *Down to Earth*, a major environmental magazine, described the book as being “almost everything one needs to understand critical aspects such as costs, safety issues and environmental implications as India embarks on an ambitious program to import foreign reactors in the wake of the poor capacity addition through the indigenous route”. The book has been welcomed by grassroots groups opposing the setting up of new nuclear power plants in India.

Ramana spent two weeks in India in February 2013 presenting the book’s main arguments and findings to a variety of audiences in Delhi, Bangalore and Chennai: the events included talks at the Indian Institute of Technology-Madras; Jawaharlal Nehru University and The Energy and Resources Institute (TERI) in New Delhi; the Indian Institute of Management, Bangalore; and a long online video interview at the Asian School of Journalism, Chennai. Many of the presentations were covered by newspapers. Ramana also wrote summary articles laying out the main findings of the book for a variety of publications around the world.

Ramana continued his work on various issues related to safety, institutional culture, economics, and liability associated with nuclear power in India. One paper examined how nuclear authorities in India responded to the Fukushima accidents and to a previous accident at one of India’s nuclear power plants, and inferred what they seem to have learned from

---

33 The book was reviewed in *Hindustan Times, Statesman, LiveMint, Hindu, Outlook, Frontline, Kafila.org, Sunday Tribune, Down to Earth, Himal, Economic and Political Weekly, ValueResearchOnline.com, New Indian Express, Pioneer and Mail Today*.
36 A full list can be found the appendix.
37 These include the Bulletin of the Atomic Scientists, Nuclear Monitor, Physics and Society, akiomatsumura.com, and ipcs.org.
these accidents. By evaluating this experience in light of a wide body of research on factors promoting reliability and safety in organizations managing complex and hazardous systems, the paper argued that decision-makers hold flawed models of how nuclear accidents occur, which work against ensuring safe and reliable operation of nuclear facilities. Another paper examined the operational experience at Indian nuclear facilities and found that actions by officials at these plants violated recommendations from safety theorists. Along with Raju, Ramana has continued to highlight the problems with the nuclear liability regime in India and the dissonance between the safety claims by nuclear vendors and their reluctance to accept even a minimal level of liability for accidents involving the reactors they supply.

Another focus of Ramana’s work on nuclear power in India was the economics of electricity from the European Pressurised Reactors (EPRs) that the Indian government proposes to import from France. Based on cost estimates for EPRs under construction in Finland and France, Ramana and Raju calculated that electricity from these reactors, without including transmission and distribution charges, would likely cost about 25 cents per kWh. Since coal plants in India produce power at around 6 cents/kWh and companies constructing solar plants are bidding around 12 cents/kWh, the government will need to offer massive subsidies in order to make nuclear electricity from imported EPRs competitive.

As part of its commitment to moving its nuclear power program from uranium-fueled reactors to plutonium-fueled breeder reactors, India is rapidly expanding its reprocessing program. Ramana has been working with Nayyar on the possibilities for and potential impacts of an accident involving a chemical explosion in the high-level radioactive waste at a reprocessing plant. The Kalpakkam Reprocessing Plant (KARP), located 65 km south of the city of Chennai (Madras), is a particular concern because a considerable amount of high-level waste has likely accumulated in its storage tanks due to delays in the commissioning of the associated plant to vitrify its waste. A loss of cooling in the tanks could lead to the dispersal of large quantities of radioactivity into the atmosphere with significant impacts on public health and the environment. Ramana and Nayyar are in the process of writing up their research.

Safety issues associated with nuclear power facilities have become an issue in Pakistan also. In November 2013, Pakistan broke ground at a coastal site close to Karachi, its largest city, on two new 1100 MWe nuclear power reactors to be supplied by China. Nayyar, Hoodbhoy and Mian raised safety concerns about the project in a co-authored op-ed for Dawn, Pakistan’s leading English language newspaper. The article, which has attracted a lot of attention, raised questions about the wisdom of Pakistan purchasing these Chinese reactors, which are still at the design stage and for which there is not even a complete safety analysis.

---

It also questioned the siting of the reactors and the feasibility of disaster planning and emergency evacuation in case of a severe accident, given an estimated population of over 20 million people living within 40 km of the site.

**Strengthening Biological Security**

*One Health and Antibiotic Resistance*

Laura Kahn has been researching the controversy over antibiotic use in livestock for her book, *Physicians, Farmers, and the Politics of Antimicrobial Resistance*. Antimicrobial resistance poses one of the greatest threats to modern medicine and public health. In the United States, medicine and agriculture have too often blamed each other for the worsening crisis.

Examining Europe’s experience on banning antibiotic growth-promoting agents is important for developing effective policies in the U.S. and other nations. Sweden and Denmark were the first two countries to completely ban growth-promoting antibiotic use in livestock and provide useful case studies.

In 1986, Sweden banned all growth-promoting antibiotic use in livestock, primarily affecting poultry and pig production. The farmers themselves initiated the ban after a newspaper article about the practice generated considerable public outrage. The ban was highly effective in stopping antibiotic growth-promoter use and curtailing therapeutic use. The price of domestic poultry increased, and broiler chicken imports increased 38-fold after Sweden joined the EU in 1995.

Pig farming experienced far more difficulties with the ban than poultry farming. From 1980 to 1990, the number of pig farms decreased by 50 percent. Swedish pork production could not meet consumer demand, and importation of pork increased 9-fold from 1994 to 2012. The consumer price index for pork increased 82 percent compared to an increase of 25 percent for poultry.

The effect of the Swedish ban on antimicrobial resistance is unclear. Sweden collected minimal antibiotic resistance data before the ban.

Denmark stopped using all antibiotic growth promoters after 1999. Pig farmers were the most affected. For over a decade, pig producers used over 75 percent of the antibiotics used in livestock. In the post-ban years, from 1998 to 2010, therapeutic use of antibiotics increased almost 120 percent. This increased use led to a 300 percent increase in *Salmonella typhimurium* resistance to tetracycline. Danish officials were so concerned that they implemented a system targeting the pig farmers, penalizing them for exceeding set antibiotic thresholds.

The ban did lead to reduction in resistant enterococci in livestock. The ban reduced, but did not eliminate, resistant organisms. Years later, they were still found in poultry. Unfortunately, resistant enterococcal infections in Danish hospitals were increasing, not decreasing. Before 2008, less than 1% of organisms were resistant. In 2012, the rate was 1.8%. Vancomycin use in hospitals increased over 500%, which is likely a contributing factor for the rise in resistance rates.
Kahn is also co-editing a multi-authored, multi-national book titled *Confronting Emerging Zoonoses: The One Health Paradigm*. She is working with Akio Yamada, PhD, a professor at the Graduate School of Agricultural Life Sciences, University of Tokyo. The book will be published by Springer Japan.

A new non-profit organization, One Health Initiative in South Asia, based in Kathmandu, Nepal, has made Kahn an international consultant, helping to formulate its mission, goals, and activities. Kahn is also a member of an advisory committee to help Kerala Veterinary & Animal Sciences University in Kerala, India establish a technology-enabled distance learning post-graduate course in One Health.

For her efforts in One Health, Kahn was awarded a plaque of recognition by The Puccini Foundation, a newly formed foundation promoting cancer research in all species based in New York City.

Chyba co-chairs a working group on antimicrobial resistance for the President’s Council of Advisors on Science and Technology.

**Biosecurity**

Kahn continues to write an online column for the *Bulletin of the Atomic Scientists*. Among other topics, she wrote about the psychological profiles of tyrants using chemical weapons and about the effect a government shutdown would have on the ability to respond to infectious disease outbreaks and bioterrorism.

Chyba continues his long-standing work on dual-use biotechnology, making this an important topic in his undergraduate and graduate courses, and speaking often with U. S. government officials on this issue. Chyba lectured for one class period on this topic to Princeton’s large undergraduate molecular biology course, with the hope of making attention to biosecurity issues a standard part of the undergraduate curriculum for biology majors.

**Robotic Weapons**

Postdoctoral research associate and physicist Mark Gubrud was with the Program for a one-year appointment beginning October 2012. He was primarily engaged with the issue of autonomous weapons. These largely entered public consciousness during the same period with the founding of the Campaign to Stop Killer Robots, an international coalition of non-governmental organizations, and culminating in the decision by the United Nation’s Convention on Certain Conventional Weapons in November 2013 to take up the issue as an agenda item for the coming year. Gubrud has been deeply involved in the background politics of the Campaign, and played a role in shaping the Campaign’s messaging. His early essay on “The Principle of Humanity in Conflict” was posted on the website of the International Committee for Robot Arms Control in November 2012.  

During 2013 Gubrud authored, with Juergen Altmann of Technische Universität Dortmund, a broad outline of proposed “Compliance Measures for an Autonomous Weapons Convention,” including general commitments and possible approaches to compliance.

---

verification for a treaty banning autonomous weapons. Gubrud and Altmann had been perhaps the first (in 2002) to propose “a ban on autonomous killer robots” as a realizable goal for preventive arms control.

In addition, Gubrud published an influential critique of the U.S. Department of Defense’s November 2012 policy directive on autonomy in weapon systems. Contrary to other reports and analyses, and consistent with the DoD’s own statements, Gubrud argued that the policy does not place a moratorium on robots that could autonomously target and kill people, but rather supported the development of all types of autonomous and semi-autonomous weapons. His analysis appeared in the Bulletin of the Atomic Scientists. A longer discussion of the effort to ban autonomous weapons by imposing a requirement for human decision and control in the use of violent force appears in the January 2014 issue of the Bulletin.

Gubrud gave several talks on this issue during his time at Princeton, including an online talk to international arms control experts, a talk in Phoenix at the University of Arizona’s Conference on Governance of Emerging Technologies, and another in Rome at the Union of Concerned Scientists’ Summer Symposium Professional Meeting, in addition to two at Princeton. He has also been engaged with this issue in commentary online, particularly on its technical aspects. Since leaving the Program, Gubrud continues to research and write on autonomous weapons, space weapons, and emerging technologies.

Space Security

Wang Ting joined SGS in 2013 as a post-doctoral researcher. He is working on the implications for strategic stability of both missile defense and anti-satellite weapons, as well as on space debris issues.

Chyba continues to conduct research and work with policy makers on issues of space policy and space security, including mitigating the asteroid impact hazard, which was highlighted by the February 2013 Chelyabinsk atmospheric explosion.

47 See, for example, Mark Gubrud, “No, Killer Robots Aren’t Secure,” available at https://medium.com/i-m-h/o/a7c6981915e1
III. Fostering the Development of Independent Technical Expertise

A Worldwide Network

SGS has for more than three decades recruited scientifically trained post-doctoral researchers for periods of two years or more and invited more senior foreign scientists who are interested in security policy to visit Princeton for a summer, semester, or sabbatical year to deepen their expertise. As noted in the South Asia section above, we also have regularly brought in each summer over the past fifteen years one to two researchers from India and Pakistan. The cumulative result of all these training activities is a worldwide collaborative network of independent, technically expert, security-policy analysts that provides the international dimension of the International Panel on Fissile Materials.

IPFM website and blog

As part of its strategy to inform the public discussion of issues related to fissile materials, IPFM has created a website, www.fissilematerials.org, which serves as an informational resource on matters related to fissile materials. The site also hosts all IPFM publications, a library of relevant historical and contemporary documents, regularly updated lists of uranium enrichment and reprocessing facilities and HEU research reactors. In January 2010 we launched an IPFM blog, which became a place where IPFM keeps a record of most important developments in the world related to fissile materials. The blog also gives us an opportunity to present our point of view to the expert community and to the public. The blog is managed from Geneva by Pavel Podvig under a consulting contract with our Program.

During 2013 the site registered about 25,000 visitors (about 15,000 unique visitors) accessing about 63,000 pages. As of December 2013 the site was getting about 2,200 visits a month, which is a good result for a specialized web resource. In addition, pdf files from the library (which includes IPFM reports and briefings as well as other publications) were downloaded about 52,000 times during the year. The most popular document, which was downloaded about 8,000 times in 2013, is the IPFM research report “Fast Breeder Reactor Programs: History and Status,” published in 2010. It was followed by IPFM annual reports issued in 2009, 2010, and 2011.

The site has an international audience. Although the United States provides the largest share of visitors, this share is only about 37%. Other countries in the top-ten list include Japan, India, the Netherlands, the United Kingdom, France, China, Canada, Germany, and Switzerland. These top-ten countries account for 77% of all visitors. The visit statistics shows that the site is used as a professional resource by many organizations that work in the field. Among the top identified visitors are universities in the United States, Europe, and Asia, the IAEA, U.S. Department of Energy and its laboratories (Sandia, Pacific Northwest, Oak Ridge, Argonne), U.S. Department of State, Nuclear Regulatory Commission, Department of Defense, U.S. Government Accountability Office, and the U.S. Senate and House of Representatives. Identified institutional visitors outside of the United States include France’s Commissariat à l’Energie Atomique, Areva, Canada’s Department of Foreign Affairs.
Affairs and International Trade, China Institute of Atomic Energy, the United Nations, and the Economist magazine.

We plan to continue developing the IPFM web site and the blog as a trusted professional informational resource as well as an important channel of disseminating the work done by IPFM. We also continue to expand the reference part of the web site and the blog. In 2013 we added a list of research and isotope production reactors and critical facilities that use HEU.

**Science and Global Security**

SGS continues to be the editorial home of Science & Global Security, which over the past 23 years has become the unofficial journal of “arms control physics.” For many researchers, the journal is the only venue for peer-reviewed publication of technically based nuclear-security policy studies and, as such, is essential to the field of security studies. It provides an intellectual common ground in which the technical-security community can come together nationally and internationally. Its articles are often referenced for backup technical analysis in articles in journals such as The Bulletin of Atomic Scientists and Arms Control Today, whose audience is the arms-control community, and Scientific American and other journals whose audience is the educated public. The journal is translated and published in Russian.

The English edition, which is published by the scientific publisher Taylor and Francis, is electronically available immediately to institutional and individual subscribers and freely available to all on the journal website after one year.

In 2013 we completed an upgrade of the web site for the journal, scienceandglobalsecurity.org, which provides access to the English and Russian archives. The upgrade introduced new design of the site and provided compatibility with academic citation systems that should improve visibility of the articles published in the journal.

During 2013 the site registered approximately 7,700 visitors (about 5,700 unique visitors) accessing almost 24,000 pages. This represents an increase of about 70% compared to 2012. As of December 2013 the site was getting about 700 visits a month. In addition to these visits, the articles in the journal archive were downloaded approximately 48,000 times (about 3,600 articles a month as of December 2013). Downloads of the Russian-language articles account for 26% of all downloads, which suggests that the translation adds a significant value to the publication.

In 2013, users in the United States accounted for about 30% of all visitors. Russia was a close second with 21% of all visitors. Other countries in the top-ten list include Ukraine, Germany, Switzerland, the United Kingdom, France, India, China, and Sweden.

**Teaching and Mentoring**

SGS faculty and researchers teach undergraduate and graduate security studies courses and policy workshops. At the undergraduate level, these include the freshman seminar, “Life in a Nuclear-Armed World,” the course, “Science and Technology of Nuclear Power: Fission and Fusion” (jointly offered by the Astrophysics, Mechanical Engineering and Physics
departments), and the upper-level Woodrow Wilson School undergraduate course “Weapons of Mass Destruction and International Security.” At the graduate level, SGS faculty teach the graduate course “Protection Against Weapons of Mass Destruction,” as well as several weeks of science and security topics that are integrated into the Wilson School’s PhD gateway course in security studies.

The Program’s integration with the Woodrow Wilson School’s Science, Technology and Environmental Policy (STEP) program has made it possible for students with science or engineering undergraduate or master’s degrees to pursue PhDs with SGS. Recently, Woodrow Wilson School faculty with interests in security organized an International Security cluster to which SGS is also affiliated. This has provided an additional route through which PhD students can associate themselves with SGS.

To further work by faculty and students on technical nuclear policy issues, Glaser has established a Nuclear Futures Laboratory in the Princeton Engineering School. The object is to provide a platform for collaboration for faculty members, students, and researchers from Princeton University and from other universities and think tanks in the United States and abroad.

At present, we have three PhD students in our program:

- Sébastien Phillipe, a second-year PhD student in Mechanical and Aerospace Engineering from France, is working with Glaser on developing a basis for nuclear archaeology in uranium enrichment plants – that is, schemes by which measurements at shutdown enrichment facilities could be used to reconstruct past enrichment activities at the facilities.

- Caroline S. Reilly, a fourth-year PhD student in Security Studies in the Woodrow Wilson School, is working with Chyba on the processes by which nuclear-armed adversaries perceive and respond to a condition of mutual vulnerability, with implications for the strategic stability of the U.S.-China relationship.

- Mark Walker, a second-year PhD student in the STEP program in the Woodrow Wilson School, is working with Glaser on nuclear transparency and verification.
APPENDIX A

Personnel


Ali Ahmad is a researcher in Nuclear Technology Policy at Princeton University's Program on Science and Global Security and Program in Science, Technology and Environmental Policy (STEP). He is also an Associated Researcher at Princeton’s Nuclear Futures Laboratory. Ali’s work covers nuclear technology and fuel cycle assessments, nuclear energy and climate change, technical and policy aspects of small modular reactors and the introduction of nuclear power to new markets. A physics graduate from the Lebanese University in Beirut, Ali holds a PhD in Nuclear Engineering from Cambridge University.

Bruce Blair (Research Scholar) specializes in U.S., Russian, and Chinese nuclear weapons policies, operations, command and control, arms control and disarmament. He is a member of the Secretary of State’s International Security Advisory Board, Co-Founder of Global Zero (an international movement for the elimination of nuclear weapons), and Chairman of the Board of the Center for Global Interests. He founded and served as president of the World Security Institute, and executive produced feature documentary films and serial programs for PBS and CNN broadcast, and for theatrical release. He was a Senior Fellow at the Brookings Institution, Project Director for the U.S. Congressional Office of Technology Assessment, and Minuteman launch control officer in the Strategic Air Command. He holds a PhD in Operations Research from Yale University. He was awarded a MacArthur Fellowship Prize for his outstanding contributions to the field of nuclear arms control and de-alerting.

Shoibal Chakravarty has a PhD in Physics from Princeton University and had been a post-doctoral researcher at the Princeton Environmental Institute. His research focuses on integrated assessment models, energy modeling, and climate change and equity. During the summer of 2013, he was at SGS working on better ways of incorporating nuclear power in integrated assessment models. Currently, he is a visitor at the National Institute of Advanced Studies, Bangalore.

Christopher Chyba (Professor of Astrophysical Sciences and International Affairs) is the Director of SGS. He has received the Presidential Early Career Award for Scientists and Engineers, and a MacArthur Fellowship Prize. His research focuses on nuclear weapons arms control, biological security, and space policy issues. He currently serves on President Obama’s Council of Advisors on Science and Technology.
Harold Feiveson (Senior Research Policy Scientist) retired in July 2013, but maintains an office at SGS, and remains a member of the International Panel on Fissile Materials (IPFM). He is the editor emeritus of *Science & Global Security*. He has a Master’s degree in physics from UCLA (1961) and a PhD in public affairs from Princeton University (1972). Along with Professor von Hippel, he co-founded the Program on Science and Global Security and was co-director until 2006.

Alexander Glaser (Assistant Professor, Woodrow Wilson School of Public and International Affairs and Department of Mechanical and Aerospace Engineering) joined the program in February 2005. His research focuses on nuclear nonproliferation and disarmament, the nuclear fuel cycle, and nuclear energy. He is a member of the Science and Security Board of the *Bulletin of the Atomic Scientists*, and co-editor of *Science & Global Security*. He is a member of IPFM.

Robert Goldston, former director of the Princeton Plasma Physics Laboratory, PPPL, has collaborated with Frank von Hippel and Professor Alex Glaser on a number of topics. Goldston contributed a section on fusion energy to a chapter on Nuclear Energy prepared by von Hippel for the IIASA Global Energy Assessment. Goldston and Glaser published on the proliferation risks associated with magnetic fusion energy, finding that they are much less than those associated with fission, if fusion power plants are subject to verification. They also published on proliferation risks associated with inertial fusion energy; their perspectives are reflected in the NAS Panel Report on inertial fusion energy. Most recently Goldston has been collaborating with Glaser and Boaz Barak of Microsoft Research on a “Zero-Knowledge” approach to warhead verification for arms control. They have received a grant from the State Department and have constructed facilities to test this technique experimentally at PPPL.

Mark Gubrud was Postdoctoral Research Associate from Oct. 2012 through Sept. 2013. Previously he taught physics at the University of North Carolina, and received his PhD in experimental physics from the University of Maryland in December 2010. His research at SGS was focused on robotic and space weapons, during a year in which the issue of autonomous weapons rose from obscurity to take a place on the global agenda. He is continuing this work as a member of the International Committee for Robot Arms Control.

Laura Kahn (Research Health Policy Scholar) has an MD from the Mount Sinai School of Medicine in New York City (1989) and Master's Degrees in public health (Columbia University 1995) and public policy (Princeton 2002) and joined SGS in September 2002. She founded the SGS Biosecurity, Biotechnology and Global Health Program, runs the SGS seminar series that explores the risks and benefits of biotechnology research, and is a co-founder of the One Health Initiative (http://www.onehealthinitiative.com). She is a monthly online columnist for the Bulletin of the Atomic Scientists and is the author of the book, *Who’s in Charge? Leadership During Epidemics, Bioterror Attacks, and Other Public
Health Crises. She is currently working on a book examining the politics of antimicrobial resistance.

Zia Mian (Research Scientist and Director of SGS’s Project on Peace and Security in South Asia) joined SGS in September 1997. He is also co-Deputy Chair of the International Panel on Fissile Materials and a co-editor of the journal Science and Global Security. Previously, he spent 1993-96 in Pakistan as a Visiting Research Fellow at the Sustainable Development Policy Institute in Islamabad and 1996-97 as a Research Fellow with the Union of Concerned Scientists in Cambridge, Massachusetts.

Seyed Hossein Mousavian (Associate Research Scholar) is a former diplomat who served as Iran’s Ambassador to Germany (1990-1997), head of the Foreign Relations Committee of Iran’s National Security Council (1997-2005) and as spokesman for Iran’s nuclear negotiators (2003-5). He has taught at Tehran University and Islamic Azad University of Iran and was Vice President of Iran’s Center for Strategic Research. He has a PhD (2002) in International Relations from the University of Kent, UK. He is currently doing research on Iran’s nuclear diplomacy, Iran-US relations and elimination of weapons of mass destruction in the Middle East.

Sébastien Philippe is a PhD candidate in applied physics in Princeton University's Department of Mechanical and Aerospace Engineering since 2012. He is a member of the Nuclear Futures Laboratory and a graduate student participant in the university’s program on Science and Global Security. His research covers topics in the areas of nuclear arms control and disarmament verification technology, nuclear archaeology and safeguards implementation. Before joining Princeton, Sébastien worked for two years in the French Ministry of Defense. He holds a M.Sc. in mechanical and design engineering from the French National Institute of Applied Sciences (INSA, Lyon).

Pavel Podvig (Associate Professional Specialist) has managed the IPFM web site and blog since joining SGS in September 2009. Since 2012 he is also working on issues of HEU minimization in Russia. He was a visiting researcher with SGS in 2000-2004 and is now based in Geneva, where he runs the “Russian Nuclear Forces” project. He was previously at the Center for Arms Control Studies at the Moscow Institute of Physics and Technology (MIPT), and has worked with MIT’s Security Studies Program and Stanford’s Center for International Security and Cooperation. He is a member of IPFM. He has physics degrees from MIPT and a PhD (2004) in political science from the Moscow Institute on the World Economy and International Relations.

M. V. Ramana (Professional Specialist) obtained his PhD in Physics from Boston University in 1994 and joined SGS in 1998. Between 2004 and 2009, he was at the Centre for Interdisciplinary Studies in Environment and Development in Bangalore, India. He is currently appointed jointly with SGS and the Nuclear Futures Laboratory and...
works on issues related to the future of nuclear energy in the context of climate change and nuclear disarmament. He is a member of the Science and Security Board of the *Bulletin of the Atomic Scientists* and shares the Indian seat on the IPFM with Professor Rajaraman.

**Caroline S. Reilly** came to Princeton in 2010 from the RAND Corporation and is now a fourth-year doctoral candidate in Security Studies at the Woodrow Wilson School. Under the guidance of advisor Christopher Chyba, she is currently working on her dissertation project, which focuses on the processes by which nuclear-armed adversaries perceive and respond to a condition of mutual vulnerability. Caroline is also teaching assistant for Alexander Glaser’s course on Science and Global Security: From Nuclear Weapons to Cyberwarfare; she received the 2013 Woodrow Wilson School Undergraduate Program Preceptor Award for this work. Caroline has a B.S. in aerospace engineering from MIT and an M.A. from the War Studies Department at King’s College London.

**Frank von Hippel** (Senior Research Physicist and Professor of Public and International Affairs Emeritus) a nuclear physicist, co-chairs the International Panel on Fissile Material. With Harold Feiveson, he co-founded the Program on Science and Global Security and was co-director until July 2006. In 2010, he was awarded the American Physical Society’s (APS) 2010 Leo Szilard Lectureship Award for outstanding work and leadership in using physics to illuminate public policy in the areas of nuclear arms control and nonproliferation, nuclear energy, and energy efficiency.

**Mark Walker** is a second-year PhD candidate in Science, Technology and Environmental Policy at the Woodrow Wilson School of Public and International Affairs. Prior to arriving at Princeton, he was involved with research at Oak Ridge National Laboratory on verification technology for nuclear arms control treaties, with a focus on active neutron interrogation techniques. In the summer of 2010, he was also an intern at the U.S. Office of Naval Reactors. He is a 2011 recipient of the Barry M. Goldwater Scholarship, and earned his bachelor’s degree in nuclear engineering from the University of Tennessee, Knoxville in 2012. He is currently completing multidisciplinary coursework in nuclear physics, security studies, and policy analysis, in preparation for his PhD qualifying exams.

**Ting Wang** joined SGS in 2013 as a post-doctoral researcher. He is working on space debris problems, missile defense and anti-satellite weapons and their relationship to strategic stability. He was previously a postdoctoral fellow at the Judith Reppy Institute for Peace and Conflict Studies at Cornell University and at the Center for International Security and Cooperation at Stanford University. He was a visiting scholar at the Union of Concerned Scientists in 2003, where he began to be interested in security issues. He received a PhD at Beijing University of Aeronautics and Astronautics in China and has worked at the Shanghai Institute of Satellite Engineering.
Visitors

**Pervez Hoodbhoy** (Visiting Research Collaborator) is a Professor in the Departments of Physics and Mathematics at Lahore’s Forman Christian College, one of Pakistan’s oldest institutions of higher education, and also continues to teach in the Department of Physics at Quaid-i-Azam University in Islamabad, from where he retired in 2010 as Chair of the Department of Physics. He is editor of *Confronting the Bomb – Pakistani and Indian Scientists Speak Out* (Oxford University Press, 2013). In 2001, with support from the Center for Defense Information, Hoodbhoy and Mian completed the documentary film, “Pakistan and India Under the Nuclear Shadow”, which Hoodbhoy directed and narrated. In 2004, with MacArthur Foundation support, they completed a second film, “Crossing the Lines: Kashmir, India, Pakistan on the India-Pakistan conflict over Kashmir”, the most likely flashpoint for a South Asian nuclear war. In 2010, he was awarded jointly with Abdul Nayyar the American Physical Society’s Joseph Burton Award for broadening the public understanding of science in Pakistan and for informing the public of the dangers of the nuclear arms race in South Asia.

**R. Scott Kemp** (Visiting Research Collaborator) initially came to SGS in June 2004 after completing a year as a Fulbright Fellow in England. After defending his PhD thesis in 2010, he became Science Advisor to the Special Advisor for Nonproliferation and Arms Control at the State Department. In 2011, Kemp returned to Princeton and resumed his research on technology change and the future of nonproliferation. In July 2012 he became Assistant Professor of Nuclear Science and Engineering at the Massachusetts Institute of Technology. He spent the summer of 2013 with SGS.

**Abdul Nayyar** (Summer Visiting Senior Research Scholar) is an independent nuclear policy analyst and consultant based in Islamabad, Pakistan. From 2011 to 2013 he was a visiting Professor in the Department of Physics at the Lahore University of Management Sciences, Lahore, having earlier taught for 35 years in the Department of Physics at Quaid-i-Azam University, Islamabad. He was previously a Senior Research Fellow at the Sustainable Development Policy Institute, Islamabad, leading their programs on security and energy issues, and on reforming the curriculum and textbooks used in Pakistan’s public schools. He has been a regular summer visitor with the South Asia Project since 1998. In 2010, he was awarded jointly with Pervez Hoodbhoy the 2010 American Physical Society’s Joseph Burton Award for broadening the public understanding of science in Pakistan and for informing the public of the dangers of the nuclear arms race in South Asia.
Administrative Personnel

Nancy Burnett (Program Manager) joined SGS in October 2008. Prior to that, she spent 22 years in various offices within the University. She manages all administrative and financial affairs for the Program.

Emad Kiyaei (Research Assistant) worked as an assistant to Ambassador Seyed Hossein Mousavian until August 2013. Emad began work with the Program in February 2012.

Ahnde Lin (Librarian) works part-time with the Program, maintaining its library of arms control and related volumes. She has been with SGS since 1994.

Geralyn McDermott (Administrative Assistant) began working with SGS in October 2012 and has been an employee of the University for a total of 9 years. She provides administrative support to the Program, the director, faculty, and program manager.
APPENDIX B

Publications and Reports


Ali Ahmad


Bruce G. Blair

Report to the Secretary of State: Security Capacity Building, Secretary of State’s International Security Advisory Board, 7 January 2013.


Christopher F. Chyba


Harold Feiveson


Fissile Material Controls in the Middle East: Steps toward a Middle East Zone Free of Nuclear Weapons and all other Weapons of Mass Destruction, International Panel on Fissile Materials, Princeton, NJ October 2013 (with Frank von Hippel, Seyed Hossein Mousavian, Emad Kiyaei, and Zia Mian)

Alexander Glaser


Licensing Small Modular Reactors, *Energy* 61, November 2013 (with M. V. Ramana and Laura Berzak Hopkins)

Resource Requirements and Proliferation Risks Associated with Small Modular Reactors, *Nuclear Technology* 184, October 2013 (with Laura Berzak Hopkins and M. V. Ramana)


Nuclear Karachi, *Dawn*, 16 December 2013 (with A.H. Nayyar and Zia Mian). **Laura Kahn**

Confronting Emerging Zoonoses: The One Health Paradigm To be published by Springer Japan 2014 (edited with A Yamada, B Kaplan, TP Monath, J Woodall, and LA Conti) Springer, Tokyo, Japan


R. Scott Kemp


Zia Mian


Wanted: An End to Nuclear Nationalism in South Asia, CTBTO Spectrum No. 20, July 2013.


Seyed Hossein Mousavian

Una nueva era nuclear en el golfo Pérsico, El País, 11 December 2013, (in Spanish)

Iran and the nuclear agreement: Trust but verify, Al-Monitor, 6 December 2013 (with Daniel Kurtzer and Thomas Pickering).

Iran nuclear deal may be start of new era in Persian Gulf, Al-Monitor, 1 December 2013 (with Shahir Shahidsaless).

Solution to Iranian nuclear dossier & its role on the Middle East Zone Free of Weapons of Mass Destruction (MEWMDFZ), European University Institute, Policy Paper No.22, Robert Schuman Centre for Advanced Studies Global Governance Program, December 2013.

Solving the Nuclear Conflict with Iran, Korber Policy Brief No.2, Korber Foundation, December 2013.

Beyond Iran's nuclear deal, Kyodo News, 26 November 2013.

The committee to save Syria, Al Jazeera America, 25 November 2013.

It was not sanctions that brought Iran to the table, Financial Times, 19 November 2013.


Finding a way out of the nuclear dispute with Iran: back to basics, British American Security Information Council, 23 October 2013 (with Paul Ingram).

The road to finalizing a nuclear deal with Iran, Al Jazeera America, 18 October 2013.

Opinion: Turkey needs to rethink its regional policy, Asharq Al Awsat, 21 September 2013.

US-Iran talks are an opportunity for reconciliation that must not be wasted, The Guardian, 18 September 2013.

The US with Iran in Syria, Project Syndicate, 11 September 2013.

Hope From Iran, but Not If There’s an Attack, The New York Times, 4 September 2013.

Sectarian War, the Major Threat to the Middle East, Asharq Al Awsat, 10 August 2013.

Nuclear Options for Iran’s New President, Asharq Al-Awsat, 9 July 2013 (in Arabic).

Five Options for Iran’s New President, Cairo Review of Global Affairs, July 2013.

Opinion: It is time for security cooperation between the Gulf States and Iran, Asharq Al-Awsat, 28 June 2013.


Iran’s Next President and The Third Nuclear Strategy, Al-Monitor, 10 June 2013.


Ten consequences of US covert war against Iran, Gulf News, 11 May 2013.

Twelve Major Consequences of Sanctions on Iran, Al-Monitor, 3 May 2013.

Globalizing Iran’s Fatwa Against Nuclear Weapons, Survival 55, no. 2, 2013.

A Seven-Point Plan to Prevent The Collapse of Syria, Al-Monitor, 7 April 2013.

Iran nuclear talks: Citizen diplomacy would build trust, Christian Science Monitor, 5 April 2013, (with William Miller).


La questione nucleare vista da Teheran: ipotesi di negoziato, Aspenia issue no. 60, The Aspen Institute, March 2013 (Italian).
Embrace the Fatwa, *Foreign Policy*, 7 February 2013.


Abdul Nayyar


Pavel Podvig


A New START Model for Transparency in Nuclear Disarmament, UNIDIR, 2013 (with Tamara Patton and Phillip Schell).


M.V. Ramana


Can Nuclear Power Be an Answer to India’s Electricity Needs?, akiomatsumura.com, 14 November 2013.

Resource Requirements and Proliferation Risks Associated with Small Modular Reactors, *Nuclear Technology* 184, October 2013 (with Alexander Glaser and Laura Berzak Hopkins).


Cost of Electricity from the Jaitapur Nuclear Power Plant, *Economic and Political Weekly* XLVIII, no. 26 & 27, 29 June 2013 (with Suvrat Raju).


India’s Breeder Dreams and Realities, *Nuclear Monitor*, 2 April 2013.


Frank von Hippel

Policy and technical issues facing a Fissile Material (Cutoff) Treaty, in Joseph Pilat, ed., Handbook of Nuclear Proliferation and Policy, to be published (with Zia Mian).


Allan S. Krass (1935-2013), Science & Global Security, to be published (with Dan Fenstemacher, Chuck Messick and Parrish Staples).


China Must Avoid Costly Trap of Reprocessing Nuclear Fuel, Chinadialogue.net, 12 July 2013 (with M.V. Ramana).


Ending reprocessing in Japan: An alternative approach to managing Japan’s spent nuclear fuel and separated plutonium, International Panel on Fissile Materials, Princeton, NJ, November 2013 (with Masafumi Takubo) . A shorter version with the title “Ending plutonium separation: An alternative approach to managing Japan’s spent nuclear fuel” was published on the website of the Asahi Shimbun, August 2013.

Fissile Material Controls in the Middle East: Steps toward a Middle East Zone Free of Nuclear Weapons and all other Weapons of Mass Destruction, International Panel on Fissile Materials Research Report #11, 2013 (with Harold Feiveson, Emad Kiyaei, Zia Mian and Seyed Hossein Mousavian).


APPENDIX C

Lectures, Talks, Workshops


Ali Ahmad

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
</table>

Bruce G. Blair

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 19, 2013</td>
<td>U.S. Armed Services Committee Hearing</td>
<td>Washington, DC</td>
</tr>
<tr>
<td>April 1, 2013</td>
<td>Witness, Secretary of State’s International Security Advisory Board</td>
<td>State Dept., Washington, DC</td>
</tr>
<tr>
<td>July 9, 2013</td>
<td>Participant, Future of Nuclear Arms Control</td>
<td>Luncheon Roundtable, Italian Ambassador to U.S. Residence, Washington, DC</td>
</tr>
<tr>
<td>July 23, 2013</td>
<td>Secretary of State’s International Security Advisory Board</td>
<td>State Dept., Washington, DC</td>
</tr>
<tr>
<td>July 30, 2013</td>
<td>Presenter, Russian NGO Capacity Building</td>
<td>Center on Global Interests Roundtable, Washington, DD</td>
</tr>
<tr>
<td>September 19, 2013</td>
<td>Secretary of State’s International Security Advisory Board</td>
<td>State Dept., Washington, DC</td>
</tr>
<tr>
<td>September 29, 2013</td>
<td>The Road to Zero</td>
<td>Congregation Solel, Highland Park, Ill.</td>
</tr>
<tr>
<td>October 23, 2013</td>
<td>Our Nuclear Choice</td>
<td>The Old Guard of Princeton, Princeton</td>
</tr>
<tr>
<td>October 31, 2013</td>
<td>Student Activism and Nuclear Weapons Elimination</td>
<td>Global Zero Student Institute, Istanbul, Turkey</td>
</tr>
<tr>
<td>November 1, 2013</td>
<td>Technological Imperatives of Nuclear Disarmament</td>
<td>Pugwash Annual Conference, Istanbul, Turkey</td>
</tr>
<tr>
<td>November 13, 2013</td>
<td>Moderator Film Panel “The Man Who Saved the World”</td>
<td>Film Premier, School of Visual Arts New York City, New York</td>
</tr>
<tr>
<td>December 3-4, 2013</td>
<td>Secretary of State’s International Security Advisory Board</td>
<td>State Dept., Washington, DC</td>
</tr>
</tbody>
</table>
## Christopher F. Chyba

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 3-4, 2013</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
</tr>
<tr>
<td>January 23, 2013</td>
<td>Origins of Life Program, Session Chair</td>
<td>Princeton Center for Theoretical Science, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>February 13, 2013</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>Eisenhower Executive Office Building, Washington, DC</td>
</tr>
<tr>
<td>February 20, 2013</td>
<td>The Asteroid Impact Hazard: How Serious a Threat, and What Should We Do?</td>
<td>Woodrow Wilson School of Public &amp; International Affairs, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>February 23, 2013</td>
<td>The Scientific Search for Life Beyond Earth</td>
<td>Alumni Day, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>March 11, 2013</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>Eisenhower Executive Office Building, Washington, DC</td>
</tr>
<tr>
<td>March 14-15, 2013</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
</tr>
<tr>
<td>April 6, 2013</td>
<td>Faculty Panel – Teaching and Research, Hosting Weekend of Admitted Students</td>
<td>Woodrow Wilson School of Public &amp; International Affairs, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>May 2-3, 2013</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
</tr>
<tr>
<td>May 23, 2013</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>Eisenhower Executive Office Building, Washington, DC</td>
</tr>
<tr>
<td>July 17-18, 2013</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
</tr>
<tr>
<td>September 11, 2013</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
</tr>
<tr>
<td>October 25-26, 2013</td>
<td>Three Lessons in Critical Thinking from Astrobiology</td>
<td>Department of Physics and Astronomy, University of Wisconsin, Eau Claire, WI</td>
</tr>
</tbody>
</table>

## Alexander Glaser

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 21, 2013</td>
<td>Increasing the Transparency of Nuclear-warhead and Fissile-material Stocks as a Step Toward Nuclear Disarmament</td>
<td>Royal Institute of International Affairs, Chatham House, London, United Kingdom</td>
</tr>
<tr>
<td>April 5, 2013</td>
<td>A New Approach to Nuclear Warhead Verification Using a Zero-Knowledge Protocol</td>
<td>Yale University, New Haven, CT</td>
</tr>
<tr>
<td>September 19, 2013</td>
<td>Nuclear Power in Integrated Assessment Models</td>
<td>University of Maryland, College Park, MD</td>
</tr>
<tr>
<td>Date</td>
<td>Title</td>
<td>Organization/Occasion</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>September 19,</td>
<td>A New Approach to Nuclear Warhead Verification Using a Zero-Knowledge</td>
<td>Global Security Technical Webinar Series</td>
</tr>
<tr>
<td>2013</td>
<td>Protocol</td>
<td></td>
</tr>
<tr>
<td>September 25,</td>
<td>Convert-and-Upgrade Strategies for Research Reactors</td>
<td>IAEA Consultancy Meeting on International Cooperation on Minimizing the Use of HEU</td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td>in Research, Vienna, Austria</td>
</tr>
<tr>
<td>September 27,</td>
<td>Verifying Nuclear Disarmament</td>
<td>Vienna Center for Disarmament and Non-Proliferation, Vienna, Austria</td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>October 27, 2013</td>
<td>Small Modular Reactors: State of Play</td>
<td>International Conference on Nuclear Technology, Nuclear Energy, and a Middle-East</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weapon-of-Mass-Destruction-Free Zone, Georgetown University, Doha, Qatar</td>
</tr>
<tr>
<td>November 27, 2013</td>
<td>How To Dismantle an Atomic Bomb: On Overview of the Global Zero</td>
<td>Massachusetts Institute of Technology,</td>
</tr>
<tr>
<td></td>
<td>Nuclear Warhead Verification Project</td>
<td>Cambridge, MA</td>
</tr>
<tr>
<td></td>
<td>Transparency of Nuclear Warhead and Fissile Material Stocks as a</td>
<td>Light of Niels Bohr’s Thought,” University of Copenhagen, Copenhagen, Denmark (with</td>
</tr>
<tr>
<td></td>
<td>Step towards Disarmament</td>
<td>Zia Mian)</td>
</tr>
</tbody>
</table>

**Mark Gubrud**

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 15, 2013</td>
<td>Stop Killer Robots</td>
<td>Program on Science and Global Security, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>May 21, 2013</td>
<td>Stopping Killer Robots: Considerations for an Autonomous Weapons</td>
<td>Conference on Governance of Emerging Technologies: Law, Policy and Ethics, Phoenix AZ</td>
</tr>
<tr>
<td></td>
<td>Convention</td>
<td></td>
</tr>
<tr>
<td>July 27, 2013</td>
<td>Stopping Killer Robots: Considerations for an Autonomous Weapons</td>
<td>Union of Concerned Scientists Professional Meeting on Science and Global Security,</td>
</tr>
<tr>
<td></td>
<td>Convention</td>
<td>Segni, Italy</td>
</tr>
</tbody>
</table>

**Pervez Hoodbhoy**

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 5, 2013</td>
<td>Confronting the Bomb: Pakistani and Indian Scientists Speak Out</td>
<td>Book launch, Carnegie Endowment for International Peace, Washington DC</td>
</tr>
<tr>
<td>March 12, 2013</td>
<td>Pakistan's Bomb - Past, Present, and Future</td>
<td>Science, Technology and Global Security Working Group, MIT, Cambridge, MA</td>
</tr>
<tr>
<td>April 22, 2013</td>
<td>The Evolution of Pakistan's Nuclear Posture</td>
<td>Belfer Center for Science and International Affairs, Kennedy School of Government,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Harvard University, Cambridge, MA</td>
</tr>
<tr>
<td>September 10,</td>
<td>Tactical Nuclear Warfare in South Asia</td>
<td>Conference on The Future of Arms Control, Heinrich Boll Stiftung, Berlin, Germany</td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>October 23, 2013</td>
<td>What if Pakistan Gave up the Bomb – a Gedanken Experiment</td>
<td>Institute of Defence and Strategic Analysis, New Delhi, India</td>
</tr>
<tr>
<td>October 25, 2013</td>
<td>What if Pakistan Gave up the Bomb - a Gedanken Experiment</td>
<td>Jinnah Institute, Islamabad, Pakistan</td>
</tr>
</tbody>
</table>
November 25, 2013 | The effects of nuclear weapons and possible outcomes of Pakistan's tactical warfare plans | Public lecture, Al-Hamra Arts Council, Lahore, Pakistan

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 16, 2013</td>
<td>One Health: A Concept for the 21st Century</td>
<td>Web Talk, MPH course planning and development, Kerala Veterinary and Animal Sciences University, Pookode, Wayanad, Kerala, India</td>
</tr>
<tr>
<td>December 7, 2013</td>
<td>Rethinking Global Health</td>
<td>Health Foo Camp, Cambridge, MA</td>
</tr>
<tr>
<td>May 5, 2013</td>
<td>One Health: A Concept for the 21st Century</td>
<td>Medical Library Association Annual Meeting, Boston, MA</td>
</tr>
</tbody>
</table>

**Laura Kahn**

**Zia Mian**

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization / Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 8, 2013</td>
<td>Political dynamics of an FMCT – Engaging Pakistan</td>
<td>Expert Roundtable: Unlocking the FMCT, British-American Security Information Council and Canadian Department of Foreign Affairs and International Trade, Carleton University, Ottawa, Canada</td>
</tr>
<tr>
<td>March 21, 2013</td>
<td>Progress report on the FMCT</td>
<td>International Panel on Fissile Materials, Royal Institute of International Affairs, Chatham House, London, United Kingdom</td>
</tr>
<tr>
<td>March 27, 2013</td>
<td>Nuclear Energy, Nuclear Weapons and Nonproliferation in South Asia</td>
<td>Paul H. Nitze School of Advanced International Studies, Johns Hopkins University, Washington, DC</td>
</tr>
<tr>
<td>July 9, 2013</td>
<td>Getting to a World Without Nuclear Weapons Policy Challenges for Managing the Global Stockpile of Nuclear Weapon Material</td>
<td>Woodrow Wilson School Summer Institute, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>Date</td>
<td>Title</td>
<td>Organization/Occasion</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>November 3, 2013</td>
<td>India and Pakistan’s Nuclear Programs</td>
<td>Short Course on Nuclear Weapons issues in the 21st Century, American Physical Society Forum on Physics and Society, Elliot School of International Affairs, George Washington University, Washington, DC</td>
</tr>
<tr>
<td>November 7, 2013</td>
<td>Nuclear Weapons and Nonproliferation in South Asia and Iran</td>
<td>Guest lecture, Politics 240/WWS 312: International Relations, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>November 14, 2013</td>
<td>A WMD-Free Zone in the Middle East: Obstacles and Opportunities</td>
<td>WMD and Security Forum: WMDFZ in the Middle East – Impact on Global Non-Proliferation Efforts, Annual Conference of Arab Institute for Security Studies, Amman, Jordan</td>
</tr>
<tr>
<td>March 8, 2013</td>
<td>Political dynamics of an FMCT – Engaging Pakistan</td>
<td>Expert Roundtable: Unlocking the FMCT, British-American Security Information Council and Canadian Department of Foreign Affairs and International Trade, Carleton University, Ottawa, Canada</td>
</tr>
</tbody>
</table>

**Seyed Hossein Mousavian**

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 28, 2013</td>
<td>How to Rescue Obama's Engagement Policy with Iran</td>
<td>University of Maryland, College Park, MD</td>
</tr>
<tr>
<td>February 4, 2013</td>
<td>Roadmap to Resolve Iranian Nuclear Dossier</td>
<td>Fordham University, New York, NY</td>
</tr>
<tr>
<td>February 23, 2013</td>
<td>Détente between Iran and the US</td>
<td>Camden Conference</td>
</tr>
<tr>
<td>February 28, 2013</td>
<td>Resolving Disputes between Iran and the P5+1 on the Nuclear Crisis</td>
<td>Pugwash Meeting, Washington D.C.</td>
</tr>
<tr>
<td>March 13, 2013</td>
<td>Iran Dialogues</td>
<td>IE School of International Relations, Madrid, Spain</td>
</tr>
<tr>
<td>Date</td>
<td>Event</td>
<td>Location/Institution</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------------------------------------------------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>March 23, 2013</td>
<td>Reviewing the P5+1 and Iran Positions on Nuclear Talks and The Way Forward</td>
<td>International Panel on Fissile Materials, London, United Kingdom</td>
</tr>
<tr>
<td>March 26, 2013</td>
<td>The impact of Iranian Nuclear Dossier on WMDFZ in the Middle East</td>
<td>British American Security Information Council, Istanbul, Turkey</td>
</tr>
<tr>
<td>March 28, 2013</td>
<td>Assessment of Iran and the P5+1 Nuclear talks in Almaty</td>
<td>International Institute for Strategic Studies, Istanbul, Turkey</td>
</tr>
<tr>
<td>April 5, 2013</td>
<td>Conference on the Future of Afghanistan</td>
<td>Harvard University, Cambridge, MA</td>
</tr>
<tr>
<td>April 15, 2013</td>
<td>Current challenges facing the Iranian nuclear negotiations</td>
<td>Korber-stiftung, Berlin, Germany</td>
</tr>
<tr>
<td>April 23, 2012</td>
<td>Resolving Deputies Between Iran and the GCC</td>
<td>Doha, Qatar</td>
</tr>
<tr>
<td>April 25, 2013</td>
<td>The Iranian Nuclear Crisis and Steps Toward a Middle East Zone Free of Nuclear Weapons and All Other Weapons-of-Mass-Destruction</td>
<td>Second Preparatory Committee for the 2015 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), Geneva, Switzerland</td>
</tr>
<tr>
<td>May 4, 2013</td>
<td>Challenges to U.S. Policy in the Middle East</td>
<td>Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>May 23, 2013</td>
<td>Iran’s nuclear dossier</td>
<td>Global Zero, University of California, Irvine, CA</td>
</tr>
<tr>
<td>June 4, 2013</td>
<td>The Shared Interests of the United States and the Islamic Republic of Iran</td>
<td>Center for Interfaith Engagement, Eastern Mennonite University, Harrisonburg, VA</td>
</tr>
<tr>
<td>June 14, 2013</td>
<td>Assessing the Prospects of a EURATOM-Treaty-Type Approach in the Middle East</td>
<td>Global Governance Program, European University Institute, Florence, Italy</td>
</tr>
<tr>
<td>June 28, 2013</td>
<td>Relations between a Nuclear Iran and the West: A Post-Election Reassessment</td>
<td>Sciences Po, Paris, France</td>
</tr>
<tr>
<td>October 10, 2013</td>
<td>Road Map for Iran’s New Foreign Policy</td>
<td>Körber Dialogue Middle East, Hamburg, Germany</td>
</tr>
<tr>
<td>November 3, 2013</td>
<td>The Neighbors and Interested Parties: Iranian perspective</td>
<td>Lehigh University’s Workshop on Global and Regional Implications of the Syrian Crisis, Lehigh, PA</td>
</tr>
<tr>
<td>November 10, 2013</td>
<td>Diplomacy, Not War, in Iran</td>
<td>The Coalition for Peace Action 34th Annual Interfaith Service and Conference for Peace, Princeton, NJ</td>
</tr>
<tr>
<td>November 26, 2013</td>
<td>Iran and the West</td>
<td>Berlin third Foreign Policy Forum, Berlin, Germany</td>
</tr>
<tr>
<td>December 5, 2013</td>
<td>The United States, Russia and the Middle East</td>
<td>John Hopkins University Paul H. Nitze School of Advanced International Studies, Washington, D.C.</td>
</tr>
<tr>
<td>December 8, 2013</td>
<td>International Interests in Middle East Security and Non-Proliferation</td>
<td>Manama Dialogue, Manama, Bahrain</td>
</tr>
<tr>
<td>December 14, 2013</td>
<td>The US and Iran: A Breakthrough Moment?</td>
<td>Asia Society, New York, NY</td>
</tr>
</tbody>
</table>
### A. H. Nayyar

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1, 2013</td>
<td>Nuclear Pakistan: An Overview of the Strategic Dimensions</td>
<td>Islamabad Literature Festival, Islamabad, Pakistan</td>
</tr>
</tbody>
</table>

### Pavel Podvig

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization / Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 23, 2013</td>
<td>A New START model for transparency and accountability in nuclear disarmament</td>
<td>2013 NPT PrepCom Side Event &quot;Practical Steps towards Transparency in Nuclear Disarmament&quot; (with Tamara Patton and Phillip Schell), United Nations, Geneva, Switzerland</td>
</tr>
<tr>
<td>April 24, 2013</td>
<td>A New START model for transparency and accountability in nuclear disarmament</td>
<td>2013 NPT PrepCom Side Event &quot;Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step toward Disarmament,&quot; (with Zia Mian and Frank von Hippel), Permanent Representation of the Kingdom of the Netherlands in Geneva, Switzerland</td>
</tr>
<tr>
<td>April 26, 2013</td>
<td>Fissile material cutoff, transparency and nuclear security</td>
<td>2013 NPT PrepCom Side Event &quot;Beyond Verification, Definitions and Scope: Other Issues to be Addressed in an FMCT&quot; (with Ignacio Cartagena and Mark Versteden), Palais des Nations, Geneva, Switzerland</td>
</tr>
<tr>
<td>May 17, 2013</td>
<td>The role of transparency in nuclear disarmament</td>
<td>Open-ended Working Group to Develop Proposals to Take forward Multilateral Nuclear Disarmament Negotiations for the Achievement and Maintenance of a World without Nuclear Weapons, United Nations, Geneva, Switzerland</td>
</tr>
<tr>
<td>September 26, 2013</td>
<td>Use of HEU in Russian research facilities</td>
<td>IAEA-Princeton Consultancy Meeting on “International cooperation in minimizing the use of HEU in research,” International Atomic Energy Agency, Vienna, Austria</td>
</tr>
<tr>
<td>Date</td>
<td>Title</td>
<td>Organization / Occasion</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>February 12, 2013</td>
<td>Nuclear Energy in India</td>
<td>Panel Discussion at Lamakaan: An Open Cultural Space, Hyderabad, India</td>
</tr>
<tr>
<td>February 12, 2013</td>
<td>Nuclear War, Nuclear Energy, and Science</td>
<td>Lecture to high school students at Vidyaranya School, Hyderabad, India</td>
</tr>
<tr>
<td>February 13, 2013</td>
<td>Nuclear Energy in India: Perspectives on its Past, Present and Future</td>
<td>Seminar, Central University, Hyderabad, India</td>
</tr>
<tr>
<td>February 14, 2013</td>
<td>Nuclear Energy in India: Past and Future</td>
<td>Indian Institute of Management, Bangalore, India</td>
</tr>
<tr>
<td>February 15, 2013</td>
<td>Nuclear Accidents and Learning: The Indian Experience</td>
<td>National Institute of Advanced Studies, Bangalore, India</td>
</tr>
<tr>
<td>February 18, 2013</td>
<td>Is Nuclear Energy the Answer to India's energy needs?</td>
<td>Loyola College, Chennai, India</td>
</tr>
<tr>
<td>February 18, 2013</td>
<td>Nuclear Energy in India: Perspectives on its Past, Present and Future</td>
<td>Madras Institute of Development Studies, Chennai, India</td>
</tr>
<tr>
<td>February 19, 2013</td>
<td>Nuclear Power: Motivations and Problems</td>
<td>National Institute of Immunology, New Delhi, India</td>
</tr>
<tr>
<td>February 20, 2013</td>
<td>Risk Perception in the Indian Nuclear Establishment</td>
<td>The Energy and Resources Institute (TERI), New Delhi, India</td>
</tr>
<tr>
<td>February 20, 2013</td>
<td>The Power of Promise</td>
<td>Jawaharlal Nehru University, New Delhi, India</td>
</tr>
<tr>
<td>February 22, 2013</td>
<td>Nuclear Energy in India: Learning from the Past, Thinking about the Future</td>
<td>Indian Institute of Technology, Madras, India</td>
</tr>
<tr>
<td>March 11, 2013</td>
<td>The Nuclear Arms Race in South Asia: The Case of India</td>
<td>Guest Lecture, Course on “Weapons of Mass Destruction”, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>March 17, 2013</td>
<td>The Potential for Severe Accidents Associated with Nuclear Power</td>
<td>Round Table on Liability Legislation in India, New Delhi, India (over Skype)</td>
</tr>
<tr>
<td>March 20, 2013</td>
<td>Nuclear Energy in India: History, Technology, and the Future</td>
<td>King’s College London, United Kingdom</td>
</tr>
<tr>
<td>April 29, 2013</td>
<td>Nuclear Arms Race in South Asia: The Case of India</td>
<td>Lecture at the Heinrich Böll Foundation, Berlin, Germany</td>
</tr>
<tr>
<td>July 29-August 2, 2013</td>
<td>Small Modular Reactors: Uranium Resource Requirements, Waste Generation and Proliferation Risk Assessment</td>
<td>Presentation at the 21st International Conference on Nuclear Engineering, Chengdu, China</td>
</tr>
<tr>
<td>August 6, 2013</td>
<td>Nuclear Energy and Climate Change</td>
<td>Presentation at the Heinrich Böll Foundation, Beijing, China</td>
</tr>
<tr>
<td>September 19-20, 2013</td>
<td>Challenges in Licensing Small Modular Reactors</td>
<td>Trilateral Meeting, University of Maryland, College Park, MD</td>
</tr>
</tbody>
</table>
October 25, 2013 | The Impact of Fukushima and Chernobyl on India’s Anti-Nuclear Movements | Conference on Traveling Norms and the Politics of Contention, Zurich, Switzerland
--- | --- | ---
October 27, 2013 | Global Context for Nuclear Power | Conference on Nuclear Technology, Nuclear Energy and a ME WMD-free Zone, Doha, Qatar
November 1, 2013 | Nuclear Energy: Issues in India and Around the World | Presentation at Prayas Energy Group, Pune, India
November 21, 2013 | Fukushima: Implications for the Understanding of Severe Accidents and the Future of Nuclear Energy | Colloquium, Department of Physics, Case Western University, Cleveland, OH
December 5, 2013 | Risk assessment methodology and nuclear reactor design | Lecture, Course on Philosophy of Randomness and Extreme Risk, Princeton University, Princeton, NJ
December 6, 2013 | The Power of Promise: Examining the Feasibility of a Rapid Expansion of Nuclear Energy in India | South Asia Institute and the Kennedy School Project on Managing the Atom, Harvard University, Cambridge, MA

### Caroline Reilly

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization / Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 22, 2013</td>
<td>Examining the Rationale for Parity in Nuclear Arms Control Agreements</td>
<td>Annual Winter Conference of the Public Policy and Nuclear Threats Program, Washington, D.C.</td>
</tr>
<tr>
<td>May 29, 2013</td>
<td>Examining the Rationale for Parity in Nuclear Arms Control Agreements</td>
<td>Center for International Security and Cooperation, Stanford University, Palo Alto, CA</td>
</tr>
</tbody>
</table>

### Frank von Hippel

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 25, 2013</td>
<td>A proposed roadmap for dealing with Japan’s spent nuclear fuel and plutonium management problems</td>
<td>International Panel on Fissile Materials Workshop, Princeton, NJ</td>
</tr>
<tr>
<td>February 7, 2013</td>
<td>Sagdeev, a band of brothers, Gorbachev and the End of the Cold War</td>
<td>Conference on Sagdeev at 80, University of Maryland, College Park, MD</td>
</tr>
<tr>
<td>February 21, 2013</td>
<td>Physicists and Nuclear Arms Control: Still Plenty of Work to be Done</td>
<td>Physics Department Colloquium, MIT, Cambridge, MA</td>
</tr>
<tr>
<td>March 19, 2013</td>
<td>A global perspective: Nature and origin of the impasse over plutonium and some options for escape</td>
<td>IPFM-Global Chance Forum, Fondation pour le Progrès de l’Homme, Paris</td>
</tr>
<tr>
<td>March 22, 2013</td>
<td>Spent-fuel management worldwide and in the U.S.</td>
<td>Annual Meeting of the IPFM, Chatham House, London, United Kingdom</td>
</tr>
<tr>
<td>April 4, 2013</td>
<td>Why do South Korea and Japan want to separate plutonium out of their spent nuclear fuel?</td>
<td>Congressional staff briefing organized by the Nonproliferation Education Center, Rayburn House Office Building, Washington, DC</td>
</tr>
<tr>
<td>April 18, 2013</td>
<td>Future of the U.S. Plutonium-disposition Program</td>
<td>Senate Armed Services Committee Staff, Russell Senate Office Building, Washington, D.C.</td>
</tr>
<tr>
<td>April 24, 2013</td>
<td>Increasing the Transparency of Nuclear-warhead and Fissile-material Stocks as a Step Toward Nuclear Disarmament</td>
<td>NPT 2015 Review Preparatory Committee Meeting, Geneva</td>
</tr>
<tr>
<td>Date</td>
<td>Event Description</td>
<td>Location/Details</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>April 25, 2013</td>
<td>Steps toward a Middle East zone free of nuclear weapons</td>
<td>NPT 2015 Review Preparatory Committee Meeting, Geneva, Switzerland</td>
</tr>
<tr>
<td>May 24, 2013</td>
<td>Escape from the plutonium (spent-fuel reprocessing) trap</td>
<td>Foreign Correspondents Club of Japan, Tokyo, Japan</td>
</tr>
<tr>
<td>July 27, 2013</td>
<td>The Uncertain Future of Reprocessing in Japan</td>
<td>Annual Meeting of the Institute for Nuclear Materials Management, Palm Desert, CA</td>
</tr>
<tr>
<td>July 17, 2013</td>
<td>Decreasing HEU Stocks and Use at Russia’s Institute of Physics and Power Engineering</td>
<td>Annual Meeting of the Institute for Nuclear Materials Management, Palm Desert, CA</td>
</tr>
<tr>
<td>September 25, 2013</td>
<td>Minimizing the use of HEU in research</td>
<td>IAEA Consultancy Meeting on “International cooperation in minimizing the use of HEU in research”, Vienna, Austria</td>
</tr>
<tr>
<td>October 6, 2013</td>
<td>The Uncertain Future of Nuclear Energy</td>
<td>Eastman Charitable Foundation South Cove Activity Center, Eastman, NH</td>
</tr>
<tr>
<td>October 9, 2013</td>
<td>Steps toward a Middle East zone free of nuclear weapons and materials and of national enrichment plants</td>
<td>Panel sponsored by a Egypt’s UN Mission and a group of NGOs during the UN First Committee Meeting, UN, New York, NY</td>
</tr>
<tr>
<td>October 22, 2013</td>
<td>Increasing the transparency of nuclear-warhead and fissile-material stocks as a step toward nuclear disarmament</td>
<td>Panel sponsored by a Japan’s UN Mission during the UN First Committee Meeting, UN, New York, NY</td>
</tr>
<tr>
<td>October 28, 2013</td>
<td>Steps toward a Middle East zone free of nuclear weapons and materials and of national enrichment plants</td>
<td>Georgetown-Princeton Conference on Nuclear technology, nuclear energy and a ME WMD-free zone, Georgetown Building, Education City, Doha</td>
</tr>
<tr>
<td>October 31, 2013</td>
<td>Steps toward a Middle East zone Free of nuclear weapons and materials and of national enrichment plants</td>
<td>Panel on A Middle East Without Weapons of Mass Destruction sponsored by the Palestine-Israel Journal, Notre Dame Center, Jerusalem, Israel</td>
</tr>
<tr>
<td>November 3, 2013</td>
<td>Scope and Verification of a Fissile Material (Cutoff) Treaty</td>
<td>APS Short Course on Nuclear Weapon Issues in the 21st Century, George Washington University, Elliot School of International Affairs, Washington, DC</td>
</tr>
<tr>
<td>December 2, 2013</td>
<td>Storage and reprocessing of spent fuel and breeder reactor research and development in Japan</td>
<td>Department of International Relations, Tsinghua University, Beijing, China</td>
</tr>
<tr>
<td>December 4, 2013</td>
<td>Roadmap for Japan away from spent fuel reprocessing</td>
<td>Panel presentation to a faction of the Liberal Democratic Party, LDP headquarters, Tokyo, Japan</td>
</tr>
<tr>
<td>December 5, 2013</td>
<td>Obstacles to change and strategies for overcoming them</td>
<td>Asahi-Princeton Symposium on Managing Spent Fuel: To Reprocess or Store? Tokyo, Japan</td>
</tr>
<tr>
<td>December 6, 2013</td>
<td>Roadmap for Japan away from spent fuel reprocessing</td>
<td>Panel presentation to a faction of the Democratic Party of Japan, Diet office building, Tokyo, Japan</td>
</tr>
<tr>
<td>December 6, 2013</td>
<td>Roadmap for Japan away from spent fuel reprocessing</td>
<td>Press Conference, Gensuikin headquarters, Tokyo, Japan</td>
</tr>
<tr>
<td>Date</td>
<td>Title</td>
<td>Organization / Occasion</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>April 6, 2013</td>
<td>An Analysis of Technical and Administrative Issues with Radiation Portal Monitors at Seaports</td>
<td>American Nuclear Society Student Conference, Massachusetts Institute of Technology, Boston, MA</td>
</tr>
<tr>
<td>April 17, 2013</td>
<td>The Nuclear Verification Dilemma</td>
<td>Science, Technology and Environmental Policy Seminar, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>July 24, 2013</td>
<td>The Nuclear Verification Dilemma</td>
<td>25th International Summer Symposium on Science and World Affairs, Segni, Italy</td>
</tr>
</tbody>
</table>
# APPENDIX D

## Program on Science and Global Security Weekly Seminars


<table>
<thead>
<tr>
<th>Date</th>
<th>Speaker</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 27, 2013</td>
<td>Itty Abraham, National University of Singapore</td>
<td>The Perils of Nuclear Proliferation (Studies)</td>
</tr>
<tr>
<td>March 6, 2013</td>
<td>Emily Meredith, Energy Intelligence Group</td>
<td>Wealth, Politics and Need: Nuclear Energy in the Middle East</td>
</tr>
<tr>
<td>April 10, 2013</td>
<td>Benoit Pelopidas, University of Bristol</td>
<td>Innovation in Nuclear Thinking: Incompetent, Dangerous or Futile?</td>
</tr>
<tr>
<td>April 26, 2013</td>
<td>Ahmed El Hady, Max Planck Institute for Dynamics and Self Organization</td>
<td>Neuroscience and Security: Intersections and Challenges</td>
</tr>
<tr>
<td>May 1, 2013</td>
<td>Hans Kristensen, Federation of American Scientists</td>
<td>The Alert Status of Nuclear Weapons and the Stability of Nuclear Deterrence after the Cold War</td>
</tr>
<tr>
<td>May 8, 2013</td>
<td>Cindy Vestergaard, Danish Institute for International Affairs</td>
<td>Starting from Zero: Greenland, Denmark and Arctic Yellowcake</td>
</tr>
<tr>
<td>May 14, 2013</td>
<td>Mark Gubrud, Princeton University, Program on Science and Global Security</td>
<td>Stopping Killer Robots: Considerations for an Autonomous Weapons Convention</td>
</tr>
<tr>
<td>June 27, 2013</td>
<td>R. Rajaraman, Jawaharlal Nehru University, New Delhi</td>
<td>Nuclear South Asia--An Update</td>
</tr>
<tr>
<td>July 18, 2013</td>
<td>Suvarat Raju, International Centre for Theoretical Sciences, Bangalore</td>
<td>The Indian Nuclear Liability Law</td>
</tr>
<tr>
<td>October 9, 2013</td>
<td>Dan Joyner, University of Alabama</td>
<td>Iran's Nuclear Program and International Law</td>
</tr>
<tr>
<td>October 10, 2013</td>
<td>David Santoro, Center for Strategic and International Studies (CSIS)</td>
<td>US-China Strategic Nuclear Dynamics: The State of Play</td>
</tr>
<tr>
<td>October 16, 2013</td>
<td>Martin Sherwin, George Mason University</td>
<td>The Cuban Missile Crisis At 50: Gambling With Armageddon And Fabricating History</td>
</tr>
<tr>
<td>October 23, 2013</td>
<td>Kathleen Araujo, Harvard University</td>
<td>Nuclear Energy at Scale: Lessons from French Civilian Program Development and Deployment</td>
</tr>
<tr>
<td>November 6, 2013</td>
<td>Alex Wellerstein, Center for History of Physics, American Institute of Physics</td>
<td>Getting to Know the Bomb: Experiments in the Public Understanding of Nuclear Weapons</td>
</tr>
<tr>
<td>November 13, 2013</td>
<td>John Downer, University of Bristol</td>
<td>Framing Fukushima: Why Disasters Don’t Destroy the Credibility of Nuclear Risk Assessment</td>
</tr>
<tr>
<td>November 20, 2013</td>
<td>Gregory Jaczko, Former Chairman, Nuclear Regulatory Commission</td>
<td>Safety, Risk and the Fukushima Nuclear Accident</td>
</tr>
<tr>
<td>December 12, 2013</td>
<td>Shen Dingli, Institute of International Studies, Fudan University, Shanghai</td>
<td>China-US Cooperation On The Global Commons</td>
</tr>
</tbody>
</table>
APPENDIX E

Sources of Funding


During 2013, SGS research was funded by Carnegie Corporation, John D. and Catherine T. MacArthur Foundation, New-Land Foundation, Carbon Mitigation Initiative, Ploughshares Fund and Rockefeller Brothers Fund.

All teaching and other academic activities of the faculty and research staff of the Program on Science and Global Security are funded by Princeton University.