Program on Science and Global Security
Woodrow Wilson School of Public and International Affairs
Princeton University

Annual Report

January 1, 2015 – December 31, 2015

Bruce G. Blair, Christopher F. Chyba, Alexander Glaser,
Robert J. Goldston, Laura H. Kahn, Zia Mian,
Seyed Hossein Mousavian, M.V. Ramana,
and Frank N. von Hippel
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I. Introduction and Summary

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

Members of SGS pursue policy objectives based upon their scientific and technical analyses of important security issues. This annual report presents the main areas of focus for SGS members, with each researcher or group of researchers summarizing their technical results, policy objectives, and policy impact.

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;
- Addressing Iran’s nuclear program;
- Minimizing nuclear threats in South Asia;
- Strengthening biological security with respect to antimicrobial resistance, natural disease, and dual-use biotechnology; 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.

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 global 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 peer-reviewed journal of arms-control science.

In 2015, SGS hosted six postdoctoral researchers from a variety of countries:

- Ali Ahmad, Lebanon (PhD Cambridge University, UK) examined nuclear technology and fuel cycle assessments, the economics of nuclear energy, and the introduction of nuclear power to new markets.
• Bernadette Cogswell, United States (PhD Vanderbilt University) examined nuclear reactor and nuclear fuel cycle safeguards, including an assessment of the viability of antineutrino monitoring as a safeguards tool, the technical challenges for arms control verification and the feasibility of nuclear energy for developing nations.

• Malte Göttzsche, Germany (PhD University of Hamburg) is interested in technical and policy issues of verifying future nuclear arms control and disarmament agreements. At Princeton, he is working on warhead authentication based on nuclear measurements and overarching verification concepts and schemes.

• Michael Schoepner, Germany (PhD Roma Tre University, Italy) focused on atmospheric transport modeling of radioactive noble gases for the verification of nuclear arms control treaties.

• Ryan Snyder, United States (PhD, University of Virginia) analyzed the technology and proliferation risks of the laser isotope enrichment that General Electric is trying to commercialize in the United States.

• Wang Ting, China (PhD Beijing University of Aeronautics and Astronautics, China) worked on a proposal to establish a liability and insurance regime able to mitigate the risks from space debris. He also studied what may have been a Chinese test of capabilities to destroy targets in geosynchronous orbit. He returned to China in October 2015.

• Yan Jie, China (PhD, University of Science and Technology, China) worked with Glaser on nuclear warhead verification. He returned in December 2015 to his position at the Institute of Nuclear Physics and Chemistry, Academy of Engineering Physics of China.

SGS faculty and researchers teach science and security courses and policy workshops for Princeton undergraduate and graduate students.

*Science & Global Security* is edited by Alexander Glaser, Zia 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. The SGS faculty and research staff includes: Bruce Blair, who focuses on technical and policy steps toward the verifiable elimination of nuclear weapons; Alexander Glaser, who researches warhead verification, nuclear-reactor, and fuel-cycle issues; Laura Kahn, MD, who works on policy related 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; Hossein Mousavian, who focuses on the resolution of the crisis over Iran’s nuclear program; 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 International Panel on Fissile Materials (IPFM) blog. Robert 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. Goldston served as acting director of SGS in spring 2015 while Chyba was on leave. 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.
Research at SGS is supported by three administrative staff members: Nancy Burnett, SGS Program Manager, Geralyn McDermott, administrative assistant, and Ahnde Lin, librarian.
II. Research and Policy Analysis

Controlling and eliminating fissile materials

During 2015, SGS work relating to controlling and eliminating fissile materials focused on:

- Informing the debate through the International Panel on Fissile Materials
- Promoting the end of plutonium separation and disposal of existing stocks
- Assessing the prospects of a phase-out of HEU fuel use in Russia;
- Promoting a phase-out of HEU use in naval reactor fuel; and
- Facilitating discussions of the proposed Fissile Material Cutoff Treaty

Much of our work in this area is with the International Panel on Fissile Materials for which the Program provides the research and administrative base. The IPFM was established in January 2006 with a five-year grant from the MacArthur Foundation, which MacArthur extended with an additional three years of support in 2011 (with a no-cost extension for a fourth year) and yet another three years in 2015. SGS also receives important overlapping support from Carnegie Corporation.

SGS continues as the policy lead for the thirteen-university Consortium on Verification Technology launched at the end of 2014 with funding from the National Nuclear Security Administration. Alexander Glaser is Princeton’s principal investigator. The focus is on developing improved verification techniques for future nuclear arms control agreements, including a Fissile Material Cutoff Treaty (FMCT) and nuclear arms reduction treaties that would require the verified elimination of nuclear warheads and verification of declarations of past production fissile material.

Informing the debate -- the International Panel on Fissile Materials

IPFM held its May 2015 annual meeting in Princeton. Discussions focused on outreach for reports nearing completion and on planned and possible new projects.

During 2015, IPFM published three reports on the web and in hard copy:

- Alternatives to MOX: Direct-disposal options for stockpiles of separated plutonium;
- Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World; and

These reports are discussed in the relevant sections below.

As of the end of 2015, the IPFM had two publications at an advanced stage of preparation and a third at an earlier stage of development:

- Prospects for reducing the use of HEU fuel in Russia;
- A total ban on the production of highly enriched uranium; and
- Shifting naval-propulsion reactors to LEU.
The next IPFM annual meeting is scheduled for March 14-16 in Washington. It will be hosted by the American Association for the Advancement of Science. Public presentations will be made on the above reports in order to highlight the larger fissile-material agenda beyond that which will be covered in the 2016 Nuclear Security Summit, which will take place in Washington at the end of March 2016.

IPFM’s website, www.fissilematerials.org, continues to serve as an information resource for governments, journalists and the concerned public on matters related to fissile materials. It makes IPFM publications available electronically – in some cases in multiple languages; it hosts a library of historical and contemporary documents, and regularly updated lists of uranium enrichment and reprocessing facilities and HEU research reactors. The IPFM blog, managed by Pavel Podvig from Geneva, makes available all previous IPFM reports and provides timely comments on important developments related to fissile materials. For further details, see the section “IPFM Website and Blog” in this report.

**Ending plutonium separation and disposal of stocks**

We continued our four-decade-old effort to inform the policy debates over plutonium separation in the countries that still separate plutonium from spent nuclear fuel (China, France, India, Japan, Russia and the United Kingdom) and countries that seek to do so (South Korea) and the emerging debates over how to dispose of the large stocks of excess separated plutonium in Japan, United Kingdom and the United States.

The IPFM report, *Plutonium Separation in Nuclear Power Programs* was published in July with selected chapters being translated into Chinese and Japanese. It examines the history, current status and prospects of programs aimed at separating plutonium for civilian use from spent fuel produced by nuclear power reactors. Chapters written by or with IPFM country experts were devoted to China (Zhang Hui), France (Mycle Schneider and Yves Marignac), India (M.V. Ramana), Japan (Masafumi Takubo), Russia (Anatoli Diakov) and the United Kingdom (Gordon Mackerron). Other chapters reviewed the rise and fall of reprocessing in Germany (Klaus Janberg), the thus far unsuccessful agitation by South Korea’s nuclear R&D community for a reprocessing program in that country (Jungmin Kang), the lack of benefits of reprocessing for spent nuclear fuel management (von Hippel) the terrible economics (MacKerron), and the radiological risk from reprocessing plants accidents (Gordon Thompson).

The report concluded that the world is closer to the end of separating plutonium (the UK has had no contract renewals) but that vested bureaucratic and industrial interests are slowing the process in some countries and interest in having a nuclear-weapon option is helping to sustain reprocessing in others.

In Japan, our collaborator Masafumi Takubo maintained his authoritative website, Kakujoho.net (nuclear information), translated some IPFM reports into Japanese, arranged

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briefings for government officials, journalists and academics and authored and co-authored many articles on reprocessing.

Zhu Xuhui, a retired senior official in the China National Nuclear Corporation, arranged for the translation of portions of the reprocessing report into Chinese in order to inform the reprocessing debate in China.

The IPFM report, Alternatives to MOX, published in April 2015, reviews programs in France, Japan, the United Kingdom, and the United States to dispose of large stocks of separated plutonium in nuclear power reactor mixed-oxide (MOX) fuel. Most of these efforts have suffered long delays and large cost increases and all have failed to reduce plutonium stockpiles. The report argues that a less costly and more effective approach would be to treat plutonium as a waste to be processed into a stable form and deeply buried. The report recommends that more than one direct-disposal approach be pursued, that the countries that share the problem of plutonium disposal collaborate on exploring direct-disposal options, and that the quantities of plutonium disposed by the weapon states be verified by the IAEA. This report has been used to help educate the U.S. Congress and inform the debates in Japan and the United Kingdom.

The Alternatives to MOX report and a report written by Edwin Lyman of the Union of Concerned Scientists helped provide a basis for a 8 September 2015 public letter to Secretary of Energy Moniz co-authored by Henry Sokolski of the Nonproliferation Education Center and von Hippel urging that the U.S. MOX program be abandoned. The letter had a significant impact within both the Administration and Congress. Especially significant in Japan was that Joseph Nye signed the letter.

Congress appropriated another $340 million to continue construction on the MOX fuel fabrication plant in South Carolina during fiscal year 2016. In good part due to a “Red Team” report commissioned by Secretary of Energy Moniz, however, both the Administration and Congress have come to understand that funding at this level only keeps the project on life support and that budgets on the level of $1 billion per year would be required to actually move it toward completion. It is generally agreed in both Congress and the Obama Administration that this level of funding is not available. The Red Team report argued, however, that direct disposal in the DOE’s deep-underground Waste Isolation Pilot Plant (WIPP) in New Mexico might be carried out at the current funding level. Congress may

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finally accept the Obama Administration’s recommendation to end the project during the fiscal year 2017 budget process.

The consulting firm High Bridge, hired by the prime contractor for the MOX plant, has published reports in support of completing the MOX plant and raising questions about the WIPP option. Lyman and von Hippel received a bi-partisan request from the staff of the Senate Appropriations Committee Energy and Water Subcommittee to comment on the High Bridge arguments and did so.6

In the light of the U.S. developments and continuing delays in its own MOX disposal program, the UK may be seriously considering direct disposal options for its huge stock of separated plutonium, the largest in the world at 123 tons as of the end of 2014, including 20 tons of plutonium that probably will never be returned to Japan. In June 2015, the UK’s Nuclear Decommissioning Authority informed a local NGO monitoring the UK reprocessing site that7

“Research work on the immobilisation of plutonium is being carried out to find out if the process can be “industrialised” so that it could be used to treat material that is unsuitable for reuse or for disposition of the entire stockpile if Government decided not to pursue reuse.”

We also wrote op-eds for different outlets,8 and briefed U.S. Senate staff in April 2015, diplomats and NGOs at the NPT Review Conference in May 2015, staffers in the White House National Security Council, the State Department and the National Nuclear Security Administration in July, and journalists in Tokyo in June and November 2015.

Our inputs helped inform the U.S. decision not to agree to reprocessing in South Korea in their April 2015 Nuclear Cooperation agreement. They also inspired a large group of attendees at the Pugwash annual meeting in Nagasaki in early November 2015 to write letters to Prime Minister Abe, the Governor of Nagasaki prefecture and the Mayor of Nagasaki, reminding them that 6 kilograms of plutonium had destroyed Nagasaki on 9 August 1945 and calling on Japan to end its plutonium separation.9 These letters drew a great deal of press attention.

Ramana continued to write in Indian outlets critiquing India’s reprocessing and breeder reactor programs. Construction of India’s Prototype Fast Breeder Reactor (PFBR) will likely

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9 http://kakujoho.net/npt/lttr_ngsk.html
only be completed in 2016 after a six-year delay.\(^\text{10}\) Ramana and a colleague have highlighted the risk of severe accidents in fast breeder reactors and critiqued the regulatory process that cleared the PFBR for construction.\(^\text{11}\) He also published op-eds in various publications in India arguing that fast breeder reactors do not offer a viable path for India to help mitigate climate change.\(^\text{12}\) He also wrote an op-ed in the U.S. arguing against resuming a U.S. research program on fast reactors.\(^\text{13}\)

**Prospects for phasing out HEU fuel use in Russia’s reactors**

Many research reactors have little security and it is much easier to make a nuclear weapon with HEU than plutonium. Reducing the use of highly enriched uranium (HEU) fuel at research reactors therefore has been a primary focus of three international Nuclear Security Summits (Washington, D.C., 2010; Seoul, 2012; and The Hague, 2014).

Russia has been cooperating with the U.S. Global Threat Reduction Initiative to convert HEU-fueled reactors in third countries and repatriate fresh and spent HEU fuel exported by the Soviet Union and Russia. It has not given a high priority, however, to converting or shutting down its own HEU-fueled research reactors. It still has about 50 such research reactors, about half of the HEU-fueled research reactors remaining in 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 workshop on “International cooperation on minimizing the use of HEU in research” with Russian and U.S. experts and officials at the IAEA’s headquarters in Vienna. A follow-on workshop, limited to the Russian experts who contributed draft chapters, was held in Moscow in June 2014. An IPFM report with papers from that workshop is near completion.

The report will provide an overview of the use of HEU in Russia— in research facilities and other applications—as well as the experience of Russia’s participation in the international programs aimed at minimizing civilian uses of HEU. Podvig found that, although Russia does not have a comprehensive program aimed at eliminating domestic use of HEU, it is undertaking a set of measures that will reduce the use of this material:

- Since LEU is becoming the norm for medical isotope production and Russia is entering the international market, Rosatom is looking at ways to fully convert its medical isotope production to LEU.
- Due to their work with the U.S. Global Threat Reduction Initiative, Russian fuel manufacturers are producing LEU fuel for Soviet-built reactors abroad.\(^\text{14}\) Rosatom is also

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\(^{10}\) [http://fissilematerials.org/blog/2015/09/india_announces_plans_for.html](http://fissilematerials.org/blog/2015/09/india_announces_plans_for.html)


\(^{13}\) M. V. Ramana, “Go slow on fast reactors,” *TheHill.com*, 3 February 2015

working on fuels for U.S.-origin research reactors. They are therefore likely to offer LEU fuel to Russian research reactors that can use it.

Overall, the effort to draw Russia into international HEU minimization program has paid off and, the difficulties notwithstanding, it can be expected that Russia will continue to reduce the use of HEU in its own research reactors, remove vulnerable material from its reactor sites, and maintain security at its sites that continue to use HEU.

**Shifting naval-propulsion reactors to LEU fuel**

For the past two decades, we have been encouraging the U.S., UK and Russian governments to transition their naval propulsion reactors to low-enriched uranium (LEU) fuel. France has made this shift and China is believed to have always used LEU fuel in its submarine reactors because of its small stockpile of HEU. U.S. submarines and aircraft carriers, however, carry more than one half the world’s naval reactors and are fueled with weapon-grade uranium.\(^\text{15}\) UK naval reactor fuel is based on U.S. designs. Russia fuels its submarines with HEU and India has built its nuclear propulsion reactors based on Russian designs. Brazil currently plans to use LEU fuel in its submarine reactor.

A 1995 report to the U.S. Congress from the Department of Energy’s Office of Naval Reactors was quite negative about the suggestion of changing over to LEU fuel. In 2012, at our suggestion, the House Armed Services Committee requested a report updating the 1995 report. The response opened the door to the possibility to developing\(^\text{16}\) “an advanced fuel system that could …allow using LEU fuel with less impact on reactor lifetime, size, and ship costs.”

In partnership with Alan Kuperman of the University of Texas at Austin we have been discussing this opportunity with the Office of Naval Reactors and key Congressional staff. In the Fiscal Year 2016 Defense Appropriations Bill for Energy and Water Development, Congress requested\(^\text{17}\) “not later than March 31, 2016, a report that describes the key goals and milestones, timeline, and annual budget requirements to develop a LEU fuel system for naval reactor cores.”

**Maintaining the prospects for a Fissile Material Cutoff Treaty**

An FMCT remains at the top the international nuclear arms-control agenda. Due to the UN Conference on Disarmament’s consensus rule and Pakistan’s continued refusal to allow

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\(^{15}\) Weapon-grade HEU contains more than 90% chain-reacting U-235.


\(^{17}\) Explanatory statement, “Division D-Energy and Water Development and Related Agencies, Appropriations Act, 2016,” [http://docs.house.gov/meetings/RU/RU00/20151216/104298/HMTG-114-RU00-20151216-SD005.pdf](http://docs.house.gov/meetings/RU/RU00/20151216/104298/HMTG-114-RU00-20151216-SD005.pdf), p. 39. Although this accompanying guidance is not in the Appropriations law itself, it conveys the intent of Congress and therefore is generally complied with by executive agencies.
negotiations to proceed, however, 2015 was another year without negotiations. Mian and von Hippel co-authored an assessment “Policy and Technical Issues Facing a Fissile Material (Cutoff) Treaty” for the Routledge Handbook of Nuclear Proliferation and Policy, published in 2015.18

France submitted a draft FMCT treaty,19 the third draft that has been submitted to the CD. The first, submitted by the G.W. Bush Administration in 2006, proposed an unverified treaty. The second, submitted in 2009 by the governments of Japan, Canada and the Netherlands, was written by the IPFM.

The French draft, like the IPFM draft, requires that civilian fissile materials produced prior to the treaty coming into force be placed under IAEA safeguards and that material declared excess for weapons purposes be placed under IAEA safeguards on a voluntary basis. It also requires verification of the non-diversion in naval fuel cycles of HEU produced after the treaty comes into force, and any previously produced HEU to be placed under IAEA safeguards.

In the absence of negotiations, to start discussions of the issues that will have to be negotiated, the UN General Assembly established a Group of Governmental Experts (GGE) from 25 states. It met in Geneva for two two-week sessions in April and August 2014 and in January and March 2015 and submitted its report to the UN on 7 May 2015.20

Pavel Podvig was asked to participate in the work of the GGE as a consultant. The documents prepared by the IPFM, including the draft FM(C)T text and IPFM reports, were cited extensively during the GGE discussions. The presentations and background materials prepared by Podvig for the GGE also drew heavily on the IPFM research.

The GGE report submitted to the UN General Assembly showed that there were many issues to negotiate including:

- Whether, in addition to banning new production of fissile material for weapons, an FMCT should ban the use in weapons of pre-existing fissile material in non-weapons use or declared excess for weapons purposes;
- How to verify the non-diversion of HEU fuel in the naval fuel cycle;
- The definition of fissile material (Russia has argued in favor of narrowing the treaty coverage to weapon-grade fissile materials, a much narrower definition than the IAEA’s definition of weapon usable fissile materials);
- Whether the accuracy of verification need be as good as in non-weapon states and whether monitoring should follow HEU and plutonium fuel in irradiated fuel;

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• Whether total fissile material stockpiles, including material in weapons, should be declared, even if they could not be verified until full nuclear disarmament is achieved;
• Whether the principal responsibility for verification should lie with the IAEA; and
• How many weapon states would have to ratify the treaty before it comes into force.

Recently, one of the U.S. presidential campaigns requested and received a policy-options paper from us on how to get the FMCT negotiations unstuck.21

Progress on the FMCT and the larger fissile material agenda would benefit from greater transparency by the nuclear weapon states about their stockpiles. The nuclear weapon states, except for the United States and to a lesser extent the United Kingdom, are largely silent about the size and disposition of their fissile material stockpiles. IPFM members Paul Meyer (a former Canadian Ambassador for Disarmament) and Henrik Salander (previously a Swedish Ambassador and Head of the Department for Disarmament and Non-Proliferation) together with Zia Mian co-authored an article for Bulletin of the Atomic Scientists making the case for accurate, up to date, and complete information and standardized reporting on fissile material and warhead stocks, including base-line historical data, by nuclear weapon states.22 These reports could be made to the Nuclear Non-Proliferation Treaty review conferences and would serve to strengthen accountability and help monitor progress towards meeting the disarmament goals of the treaty. Mian and Glaser provided an updated assessment of nuclear weapon state transparency in the wake of the 2015 NPT review conference as part of Global Fissile Material 2015.

The Future of Nuclear Power

SGS continued to research developments that affect the future of nuclear power. In the last year, SGS researchers have focused in particular on prospects and challenges for nuclear energy in the Middle East, on technical and policy analysis on small modular reactors (with electrical power outputs of less than 300 MWe) that are under development, and the accident risks associated with nuclear reactors. Work on nuclear energy issues in Pakistan and India is reported in the South Asia section.

Nuclear energy in the Middle East

In the Middle East, many countries, including Saudi Arabia, Turkey, Jordan, Algeria and Egypt, are in various stages of planning the construction of their first nuclear power reactors. SGS researchers continued to examine the potential role and challenges emanating from the deployment of nuclear power in the region.

Ramana and SGS post-doc Ali Ahmad studied the economics of nuclear power in the countries belonging to the Gulf Cooperation Council (GCC) by comparing the cost of nuclear power to electricity generated using local natural gas and solar. Their analysis shows that the prices at which natural gas is traded in the international market makes gas-fired less costly

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than nuclear power. They also found that solar power is likely to be less costly than nuclear electricity within the time frame when a new nuclear power plant could become operational. They published a number of op-eds for regional outlets reporting their findings. Ahmad also wrote a paper on Jordan’s nuclear power plans highlighting the economic risks involved in such a huge commitment and the country’s inadequate regulatory capacity to manage the safety risks.

Ramana and Mian wrote an article in the Bulletin of the Atomic Scientists on the intense competition between leading vendors of nuclear power reactors, from France, Japan, South Korea, Russia, and the United States, in the Middle East as reactor markets dry up at home. They find that these companies, often tied to respective governments or backed by them, have been pursuing reactor deals in Saudi Arabia, Egypt, Jordan, Turkey and the United Arab Emirates, in some cases building on legacies left over from Cold War Atoms for Peace programs. Given nuclear ambitions in some Middle East states, these efforts are creating a troubling momentum that threatens the hopes for well-being and peace in the region.

Along with nine others who focused on different fields related to energy, Ramana was invited to write an overview of the challenges faced by nuclear power in the inaugural issue of Nature Energy. Ramana argued that due to its lack of economic competitiveness and the rapid declines in the costs of renewable energy sources, globally the share of nuclear power in electricity generation will continue to decline. Because of this decline, Ramana argued elsewhere in various outlets, the potential contribution of nuclear power to climate mitigation will be limited at best.

**Small modular reactors**

Glaser, Ramana, and Ahmad published an overview of small modular reactors (SMRs) with Robert Socolow of the Princeton Environmental Institute—explaining the issues that must be kept in mind when considering this energy option—especially nuclear proliferation. They highlighted the fact that some of these designs require fuel processing to remove certain isotopes whose build-up in the reactor shuts down the nuclear chain reaction, and how these

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processing facilities could be modified to separate plutonium.

Developing countries with small grids and limited financial resources are supposed to be an important market for SMRs, but so far none of them have actually purchased one. Jordan, a prime candidate, has recently entered into an agreement with Russia to acquire two large conventional light water reactors. Ramana and Ahmad have written a paper arguing that although SMRs would be much better suited to Jordan’s circumstances, the SMR option raises new problems, including locating sites for multiple reactors, finding water to cool these reactors, and the higher cost of electricity generation.  

Priscilla Agyapong, a Princeton senior who did her thesis with Ramana, interviewed officials at Ghana Atomic Energy Commission (GAEC) to understand why Ghana, another country that has been considered a potential customer for SMRs, may also purchase a large reactor from Russia. Ramana and Agyapong argue that because of its lack of political clout to force through the purchase of a nuclear power plant, GAEC prefers a large reactor in comparison to an SMR because it allows GAEC to position itself as a complete, one-stop solution to Ghana’s electricity crisis.  

In June 2015, Ramana and Bernadette Kafwimbi Cogswell, an SGS post-doc, organized a workshop in Jakarta in collaboration with the Indonesian Institute of Energy Economics (IIEE) on “Nuclear Power and Small Modular Reactors (SMRs) in Indonesia: Potential and Challenges”. A wide variety of policy makers and officials attended. Ramana’s presentation on SMRs led to an invitation from Indonesia’s Nuclear Energy Regulatory Agency (Bapeten) for a special seminar to their staff about SMRs. The findings are being written up and will be published as a report in English and Bahasa by IIEE.

Reactors with much lower power capacities are not new and Ramana examined the history of small reactors constructed in the United States to draw a cautionary message. All of them shut down well before their licensed lifetimes because of poor economics. Ramana contributed a section on SMRs to the 2015 World Nuclear Industry Status Report. Along with Benjamin Sovacool, currently at the Science Policy Research Unit at the University of Sussex, Ramana examined the strategies used by scientists and technologists associated with the nuclear industry to build support for SMRs. They identify five rhetorical visions imbued with elements of fantasy that cater to various social expectations that together serve to attract

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32 Some of the institutions that sent representatives include Directorate of Various New and Renewable Energy, Directorate General of Electricity, Directorate of Defense Strategy - Ministry of Defense, National Nuclear Energy Agency (BATAN), and the National Energy Council.
33 M. V. Ramana, “Challenges in Licensing Small Modular Reactors,” Briefing for Indonesian Nuclear Regulatory Agency (Bapeten), Jakarta, 26 June 2015.
political and financial support and erase previous nuclear failures from public discourse. Several SMR designs use thorium instead of uranium-238 to produce chain-reacting U-233 instead of plutonium. Alexander Glaser and Ahmad developed computer models of the nuclear cores of these reactors and showed that the proliferation risks associated with molten salt reactors would depend on specific design choices, and some choices open up pathways for acquiring weapon-usable materials.

**Nuclear power safety**

Along with Mengdi Wang, a faculty member specializing in operations research and a student, Jiaxing Sun, Ramana and Glaser studied how the characterization of nuclear power in the complex energy-economy-climate models used to explore global energy futures could better reflect the risk of severe reactor accidents and their economic impacts. They find that incorporation of the possibility of an accident in these models would result in a reduction of nuclear power deployment in the optimal scenarios to meet climate mitigation targets.

John Downer from the University of Bristol and Ramana have been studying the process through which the U.S. Nuclear Regulatory Commission licensed the AP1000 reactor despite concerns about the structural integrity of the outer shield building and the vulnerability of its containment to corrosion. They find that the NRC’s decision was based on contested judgments, raising questions about the reliability of its assessment process. This work is being written up.

Frank von Hippel has continued on with the Congressionally-mandated National Academy of Sciences committee on Lessons Learned from the Fukushima Accident. The Committee’s first report on the nuclear reactor accidents was not very interesting. A second volume nearing completion should be more interesting. It focuses on the potentially much larger catastrophe had the water in the spent fuel pool of unit #4 boiled down and uncovered the fuel in the pool. Once that report is released in early 2016, von Hippel plans to write an article expanding on the findings that he has contributed.

As the country with the largest number of reactors under construction, safety in the Chinese nuclear industry is of immense significance. Along with Amy King of the Australian National University in Canberra, Ramana explored the tension between China’s plans for a rapid expansion of nuclear power and its stated commitment to nuclear safety. They showed that although various safety measures have been implemented since the accidents at Fukushima, when decisions that might result in greater safety compete with other priorities, the other priorities often win over safety. Based on this research, King and Ramana also

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wrote an op-ed for the online bilingual website China Dialogue explaining the special risks posed by constructing nuclear reactors inland instead of near the coast.\textsuperscript{40}

Tadahiro Katsuta, an associate professor at Meiji University in Japan, is visiting SGS for this academic year. He has written an article for the Bulletin of the Atomic Scientists highlighting the flawed safety case for Japan’s Kyushu Electric Power Company restarting the Sendai nuclear power plant last year despite widespread public protests against the move.\textsuperscript{41} Since then he has been examining the safety review of the Rokkasho reprocessing plant that is being conducted by the Nuclear Regulation Authority and if the new regulatory standards and safety countermeasures proposed by the regulators are sufficient to ensure that Rokkasho will be adequately safe.

**Nuclear Arms Control and Disarmament**

**Nuclear archaeology**

In 2015, we have continued our work on developing the approaches and techniques needed to establish confidence in the correctness and completeness of “baseline declarations” of nuclear-warhead and fissile-material inventories that weapon states will likely have to make as deep cuts in nuclear arsenals proceed and countries embark on the path toward nuclear disarmament. To account for fissile material stockpiles as accurately as possible, there is growing interest in a set of methods and tools that can be used to characterize past fissile material production activities, using measurements and sampling at production and storage sites. This has been dubbed nuclear archaeology, which is based on methods borrowed from nuclear forensic analysis.\textsuperscript{42}

As one step in this work, Glaser and Mian have been working with other members of the International Panel on Fissile Materials to identify and compile a preliminary list of fissile material production facilities in nuclear weapon states that have been used for making material for weapons. These facilities, many of which were secret and remain off-limits to outside inspection, include plutonium production reactors, reprocessing plants and enrichment plants. The status of these facilities, most of which are shut down and some of which have been converted to non-weapon purposes, remains to be verified.

Developing nuclear archaeology approaches may best be done jointly in projects that bring together weapon states with non-weapon states and the International Atomic Energy Agency. Nuclear archaeology analysis should be possible at shut down but intact production facilities and to some extent at facilities that have been decommissioned and dismantled. Analysis of key components and waste materials that remain in situ


\textsuperscript{41} Tadahiro Katsuta, “Why was the Sendai Nuclear Power Plant Restarted?,” Bulletin of the Atomic Scientists, 12 August 2015, http://thebulletin.org/why-was-sendai-nuclear-power-plant-restarted8644.

or storage pending final disposal may offer constraints on fissile material production at
the plant, if appropriate methods can be developed.43

Given the sensitivity among some weapon states about former fissile material production
sites, Glaser identified a small number of possible test beds for nuclear archaeology in non-
weapon states where it may be more practical to establish a basis for such projects. Non-
weapon states with possible facilities of interest for nuclear archaeology include Japan,
Sweden, Germany, Norway and Canada. IPFM members in these countries have expressed
an interest in supporting this effort but it has not made as much progress as hoped. In 2015,
with support from IPFM member Paul Meyer (a former Canadian ambassador), Glaser
developed a memo for the Canadian Nuclear Laboratories on a possible nuclear archaeology
project at the NRX reactor at the Chalk River site. Also, in 2015, Glaser worked with Peter
Dessaules from the U.S. Department of Energy to develop a project to understand the origin
of a more than 10 per cent shortfall (equivalent to over 10 kg, or enough for about two
weapons) in the plutonium accounts for the West-Valley (New York) reprocessing plant in
1969. One possible explanation may be that less plutonium was contained in the spent
nuclear fuel than had been assumed by the reactor operators.

Nuclear warhead verification

Activities in this area focus mainly on the research and development of technologies that
can help address fundamentally new verification challenges for nuclear arms control.
These will emerge, in particular, when future treaties begin to limit stockpiles of tactical
and non-deployed weapons instead of just deployed weapons on delivery vehicles. Under
these circumstances, inspectors would have to confirm that the number of declared items is
correct. Inspectors would also have to confirm the authenticity of nuclear warheads prior to
dismantlement. Both tasks may involve procedures that put at risk classified or otherwise
sensitive information. Our research is described in more detail below.

1. Zero-knowledge nuclear warhead verification. Our current work is focusing on
the experimental proof of the concept proposed by Glaser, Barak and Goldston (Nature,
2014). In 2015, we built a complete experimental apparatus at PPPL and conducted an
extensive measurement campaign focusing on zero-knowledge fast neutron tomography. The
goal was to assess the repeatability of results, increase the statistics of the measurements in
order to detect smaller changes in neutron opacity, and optimize the various steps of our
inspection protocol. We performed over a hundred radiography experiments with 14-MeV
neutrons using test items represented by patterns of steel and aluminum cubes. These
measurements confirmed that the results were zero-knowledge when valid items were tested
and identified invalid items for four different diversion scenarios.44 We have also expanded
the concept to include new types of measurements.45 Overall, our objective is to identify

43 Sébastien Philippe, Alexander Glaser, “Nuclear Archaeology for Gaseous Diffusion Enrichment Plants,”
Demonstration of a Physical Zero-Knowledge Protocol for Nuclear Warhead Verification,” 56th Annual INMM
Meeting, 12-16 July 2015, Indian Wells, California.
45 Yan Jie and A. Glaser, “Two-Color Neutron Detection for Zero-Knowledge Nuclear Warhead
Verification,” 56th Annual INMM Meeting, 12-16 July 2015, Indian Wells, California.
minimally intrusive and adaptive protocols. The work builds upon the cryptographic literature and provides guidelines on how to construct and use physical interactive protocols with zero-knowledge property for inspections. It covers relevant topics such as perfect and statistical zero-knowledge, properties of the prover and the verifier, trusted and non-trusted apparatus and detectors, physical commitment schemes, composition of zero-knowledge protocols, and non-interactive zero-knowledge proofs. Following our preliminary findings presented at the last INMM annual meeting, we continue to develop the conduct of operations for our zero-knowledge verification protocol and to theorize the design of inspection protocols more broadly.

2. **Virtual gamma-ray spectrometry for template-matching nuclear warhead verification.** While the main focus of our research remains on neutron-imaging techniques, we also consider the use of gamma measurements combined with the template method for potential application in verification applications. In 2014/2015, Glaser advised an engineering senior thesis comparing gamma benchmark spectra from unclassified reference objects against simulated spectra generated with MCNP to determine the sensitivity and requirements for the method for verification applications. Based on this research, we presented a paper at the INMM Meeting in July 2015, and we have continued to refine the results for article publication. We have also proposed benchmark experiments that will be carried out at the Device Assembly Facility in Nevada in June 2016.

3. **Confirming Numerical Limits with Minimally Intrusive Verification Approaches.** Verifying agreements that limit the total number of weapons in the arsenals would require the ability for inspectors to count individual warheads (rather than launchers), both deployed and non-deployed, to confirm that the declared numbers are not exceeded. Typically, this can be accomplished by “tagging” treaty-accountable items with unique identifiers (UIDs), which transforms a numerical limit into a ban on untagged items. Attaching UIDs directly to nuclear warheads or warhead components could be problematic due to a range of concerns by the host related to safety, security, and intrusiveness. To resolve this dilemma, we are revisiting the idea of a fundamentally different approach for warhead counting and tagging: instead of attaching UIDs directly to treaty-accountable items or to containers in which they may be stored, we explore the concept and use of so-called “buddy tags.” Sandia National Laboratories first proposed this concept in the early 1990s. The main effort in this area is currently supported by a grant from the U.S. Department of State (Bureau of Arms Control, Verification, and Compliance) to our group and Sandia National Laboratories.

4. **Warhead Dismantlement Facility and Managed-Access Simulator.** Developing inspection protocols is an important aspect for treaty verification, especially if confidential or classified information has to be protected. To further support research in this area, we have recently acquired a full-motion virtual reality system to develop inspection protocols for future arms-control treaties, which might involve warhead dismantlement or managed access.

to military nuclear sites. We plan to develop this system into two directions: at Princeton, we are deploying a high-performance platform for research and development; in addition, we also plan to develop a “mobile version” of the system that can be used for live demonstrations and enable domestic and international collaborations with other groups. Tamara Patton, an expert on geospatial and data visualization, has recently joined our program as a PhD student in the WWS to work on this project. We have also examined the potential of crowdsourcing and, in particular, possible hardware and software challenges for nuclear disarmament verification as a potential source of innovation in this area.\textsuperscript{48}

We have also engaged an international audience in the discussion and research on warhead verification. Our post-doc Yan Jie, who was part of our group for 18 months from the China Academy of Engineering Physics (CAEP), has completed a review of inspection systems for warhead verification, which highlights in particular little-known recent developments underway in China.\textsuperscript{49} Another paper on “Minimally Intrusive Approaches to Nuclear Warhead Verification” by Glaser and Yan Jie is forthcoming in an edited volume. In June 2015 in Beijing, our group held a joint workshop on verification of nuclear disarmament with the Program for Verification Technologies Studies (PVTS) of China’s Academy of Engineering Physics (CAEP, China’s Los Alamos). This led to an agreement for cooperative research. Cooperative research on the same topic between the CAEP and the U.S. national nuclear laboratories broke down following a 1999 U.S. House of Representatives report that made exaggerated allegations that China had stolen U.S. nuclear weapon designs.

**Nuclear disarmament policy**

Bruce Blair, a co-founder of the Global Zero international movement for the elimination of nuclear weapons, has maintained his focus on the de-legitimization and the de-alerting of nuclear weapons, in response to the prolonged impasse in U.S.-Russian negotiations to reduce nuclear arms. He also continues to promote the broadening of official arms control beyond the bilateral and into the multilateral arena, and to facilitate collaboration among former senior officials and military officers (so-called track 2 dialogue) from the nuclear and key non-nuclear countries in order to fill the vacuum of moribund official dialogue (so-called track 1 dialogue).

Apart from their cooperation in reaching the nuclear deal with Iran, U.S.-Russian diplomatic relations further deteriorated in 2015. Tensions over the Ukraine crisis flared frequently, often accompanied by low-level NATO and Russian military encounters that risked causing accidents and escalation. Nuclear threat warnings emanated from senior officials or were implicit in exercises and other operational activities. The climate for security cooperation, including new attempts at nuclear arms regulation, worsened. Russia’s insistence that any future bilateral negotiations to reduce strategic arms simultaneously address missile defenses, ‘prompt global strike’ vehicles, conventional arms imbalances, and space warfare programs in order to ensure equal security for both nations further thwarted progress on re-starting


nuclear talks. Another festering obstacle in 2015 was the inability to resolve the question of Russia’s testing of a ground-launched cruise missile in apparent violation of a key treaty banning intermediate-range nuclear weapons. Russia rejected the allegation and the question remains unresolved, casting doubt not only on the future of this particular treaty but also on Russia’s commitment to comply with other existing nuclear arms treaties. The United States has indicated that it will pursue unspecified countervailing responses if Russia does not return to compliance (even though Russian deployments of intermediate-range ground-launched cruise missiles may be motivated mainly by unconstrained Chinese, Indian, and Pakistani deployment of intermediate-range missiles). These developments, together with the fact that both sides remain committed to extensively modernizing their land-, sea-, and air-based strategic nuclear forces, do not bode well for progress on bilateral nuclear arms reductions.

On the other hand, both sides have dutifully adhered to the New START Treaty negotiated by Presidents Medvedev and Obama in 2010, and their drawdown continues on schedule. Despite the INF imbroglio, both sides appear to attach importance to preserving treaties already in existence, and to avoiding sparking a new nuclear arms race. Growing economic pressures on military spending is not only slowing the pace of new strategic investments but also creating incentives to further downsize nuclear arsenals.

In seeking to re-vitalize the nuclear arms control agenda, Blair’s efforts concentrated on two avenues. The first track is the de-legitimization of nuclear weapons. This approach has gained visibility in recent years through a series of government-sponsored conferences (in Norway, Mexico, and Austria) devoted to ‘fact-based’ presentations of the risks and humanitarian consequences of the use of nuclear weapons. After giving presentations at two of these conferences, Blair formed in 2014 a high-level Global Zero Commission on Nuclear Risk Reduction chaired by Gen. (ret.) James Cartwright (former head of U.S. Strategic Command) and composed of 40 former senior military commanders as well as former defense and foreign ministers, and national security advisors from all the nuclear weapons countries except North Korea, to assess the risks of nuclear weapons use around the world. In 2015, the commission issued a report that examined all of the nuclear weapons arsenals in nine nations and their supporting command, control, communications, and early warning networks and identified a multitude of scenarios in which such risks are significant, and in many cases were increasing – risks of accidental detonations, unauthorized use, mistaken launch on false warning, intentional use resulting from an escalating crisis that spins out of control, and capture/theft/purchase of a nuclear weapon by terrorists.50 The growth of increasingly sophisticated cyber warfare programs exacerbates all of these problems. The commission determined that the risks of nuclear weapons use have not only increased but that the adverse consequences for human health, society, and the environment are worse than previously believed, even if nuclear weapons are used on a relatively small scale, and also are far beyond the capacity of nations and organizations to ameliorate.

50 The nine countries possessing nuclear weapons today are fielding new types of weapons, shortening the time needed to employ them, and dispersing them more widely on ever-higher states of alert (attack readiness). The danger is thus increasing that these weapons will be used – deliberately, or as a result of inadvertent escalation, hasty decision making, miscalculation, unauthorized acts, or capture and use by terrorists. See Global Zero Commission on Nuclear Risk Reduction, “De-Alerting and Stabilizing the World’s Nuclear Force Postures,” April 2015.
De-alerting nuclear weapons

The second track of Blair’s recent work seeks to reduce these risks of nuclear weapons use through various confidence-building measures including changes to the nuclear operational postures of the parties, particularly changes that would take nuclear missiles off of hair-trigger alert. The Global Zero Commission chaired by Gen. (ret.) Cartwright concluded in its 2015 report that taking strategic nuclear forces off of high alert status would virtually eliminate a host of current capabilities and risks – sudden deliberate strikes, mistaken launch on false warning of incoming ‘enemy’ warheads, accidental detonations and unauthorized launch by insiders or by outsiders exploiting cyber vulnerabilities. The report calls upon the United States and Russia to stand down their launch-ready arsenals, and describes a wide variety of ways to carry out this ‘de-alerting’. The report also discusses the importance of locking down the current low alert readiness of the nuclear arsenals of the other seven countries possessing such arms.

With the support and encouragement of a number of governments and foundations which endorsed the report, the Commission under Blair’s guidance as study director initiated projects to further develop confidence-building measures that promise to reduce both global and regional risks. A Commission focused on reducing nuclear risks through security cooperation in the Asia Pacific region began work in 2015, and plans were laid to partner with a government to convene a roundtable in a European capitol on global nuclear risk reduction. The goal is to consider and recommend de-alerting and other confidence-building measures that could help prevent crises from erupting and escalating, deliberately or inadvertently, to the level of nuclear threat or conflict. In parallel, Blair continued to collaborate with Matthew McKinzie (Natural Resources Defense Council) and Hans Kristensen (Federation of American Scientists) in preparing tabletop exercises to assess the stability of de-alerted nuclear postures during a crisis. The results of these exercises will help devise de-alerting options that maximize crisis stability.

Blair also continued his work on assessing the conventional forces dimension of strategic stability. He updated his calculations of the lethality of U.S. conventional weapons in operations against a spectrum of strategic targets including Russian and Chinese hardened missile silos. These calculations will help gauge the potential for conventional arms to destabilize 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.

Finally, Blair continued his efforts in mentoring international students’ college and high school chapters of Global Zero around the world.

Strategic stability

Caroline Milne, completing her PhD supervised by Chyba, continued her examination of mutual nuclear vulnerability. Two nuclear-armed adversaries are mutually vulnerable when neither can be confident in its ability to carry out a disarming first strike against the other without incurring intolerable costs. However, these parties may not realize the condition has emerged, or they may also attempt to deny or overcome it. Milne’s project asks: under what conditions do key actors recognize the existence and inescapable nature of mutual vulnerability? She first approaches this phenomenon historically, using archival evidence to
trace the manner in which U.S. and Soviet decision-makers came to acknowledge the reality of mutual vulnerability. She then compares this case to the ongoing confrontation with mutual vulnerability by the United States and the People’s Republic of China, using in-depth interviews with experts and officials to illuminate the steps that these (and future) nuclear rivals may take to cope with this dilemma in ways most conducive to strategic stability.

**Addressing Iran’s Nuclear Program**

In 2015, 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. Mousavian has played a key role in helping Iran and American nuclear negotiators in understanding each other. He also worked to find creative compromises that would respect the red lines of both sides and we were able to brainstorm with him about technical ideas that could expand the negotiating space.

In this way, we developed one idea that may have helped solve the impasse over Iran’s Arak reactor and another that may have narrowed the gap on the permitted size of Iran’s enrichment program. Ambassador Mousavian and the Princeton group contributed to the success of the negotiations by developing suggestions to resolve key sticking points in the talks and inject them directly into the negotiations. These negotiations culminated with the P5+1 and Iran final agreement to the Joint Comprehensive Plan of Action on July 14, 2015. Subsequently, the UN Security Council unanimously approved the accord on July 20, 2015.

Over the past year, Mousavian also has been advancing ideas for making progress towards a Middle East Nuclear Weapons Free-Zone (ME-NWFZ). Emad Kiyaei and Sina Toossi worked as independent research assistants on this project with Mousavian, with responsibility for researching, drafting and editing op-eds, scholarly articles and lectures. This work has been supported by grants from the Ploughshares Fund and Rockefeller Brother Fund.

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. He contributed a chapter titled “The Iran nuclear dilemma: the peaceful use of nuclear energy and the NPT’s main objectives,” published in the book *WMD Arms Control in the Middle East: Prospects, Obstacles and Options* (Ashgate, February 2015), edited by Harald Müller & Daniel Müller. In the chapter, Ambassador Mousavian first details the NPT’s three core goals, then highlights examples that have undermined all three main goals of the treaty. Mousavian follows this with a suggested series of principles that would be essential to guarantee ‘nuclear technology for all, nuclear weapons for no one’. His recommendations include making nuclear arms regulation comprehensive, universal and mandatory. Finally, he asserts that the resolution of the Iranian nuclear file can serve as a model for non-proliferation in the Middle East and step toward realizing a WMD-free Middle East.

Another paper, “Building on the Iran Deal: Steps Toward a Middle Eastern Nuclear-Weapon-
Free Zone,” was co-authored with SGS colleagues Alexander Glaser, Zia Mian and Frank von Hippel (Arms Control Today, December 2015). The paper provides the essential technical steps toward a nuclear-weapons-free zone in the Middle East by building on the set of important limitations, verification and related transparency measures on Iran’s nuclear activities following the July 20th Nuclear Agreement between Iran and the world powers. Furthermore, it proposes the P5+1 and regional countries to use the restraints outlined in the agreement as steps toward establishing a Middle Eastern nuclear-weapon-free zone, preferably as part of a regional zone free of all weapons of mass destruction (WMD). Ambassador Mousavian also wrote another major essay, “America’s Middle East Challenge,” published by the Cairo Review in April 2015.

Mousavian’s papers have provided the basis for briefings to politicians, policy makers, academics, the media and the general public on the elements of a possible US-Iran rapprochement. In the past year, he has written many op-eds, including for the New York Times, Foreign Policy, and elsewhere, and given many interviews to US and international TV and radio programs. He has also been widely quoted in international media and in the Iranian press.51

Mousavian has also invested heavily on providing briefings to Iranian politicians, policy makers, academics, the media and the general public on the aftermath of the nuclear deal (JCPOA) and the elements of a possible US-Iran cooperation on the crisis in the Middle East such as Syria, Yemen, Iraq, and the fight against extremism and terrorist groups such as ISIL. He has over 100 articles and interviews with major Iranian news agencies, and his interviews have appeared in major Iranian newspapers and magazines.

**Nuclear Threat Reduction in South Asia**

SGS set up its Project on Peace and Security in South Asia in 1997 to inform nuclear policy debates in India and Pakistan and 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 South Asian nuclear weapons and nuclear energy policy and to develop analysis, arguments and educational materials that can inform the debate on these issues.

In 2015, the summer visitors were: Professor A.H. Nayyar, who retired from the Department of Physics, Quaid-i-Azam University (Pakistan’s leading public university) and was until the end of 2012 Visiting Professor in the Department of Physics at the Lahore University of Management Sciences (a leading private university), and Professor Pervez Hoodbhoy, a leading physicist also from Quaid-i-Azam University and since 2013 the Professor for Mathematics and Physics at Lahore’s Forman Christian College. Nayyar and Hoodbhoy jointly received the 2010 American Physical Society 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.”

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51 These writings and interviews are available on Mousavian’s webpage: http://www.princeton.edu/sgs/faculty-staff/seyed-hossein-mousavian/.
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, the two countries have expanded dramatically both their capabilities for producing plutonium and highly enriched uranium—the key ingredients for nuclear weapons—and their capabilities to deliver nuclear weapons by aircraft, by land-based missiles, and from the sea. There have been no significant negotiations on measures to restrain these nuclear weapon programs.

Pakistan in particular has been expanding its nuclear complex and arsenal. In 2015, Pervez Hoodbhoy wrote an article in Pakistan’s leading newspaper, Dawn, exploring what is driving expanding nuclear arsenals in South Asia, highlighting the role of an emerging nuclear military-industrial complex, and the risks that come with it.\(^{52}\)

Among the new nuclear weapon systems that Pakistan Strategic Plans Division has been developing is what its founder General (retired) Khalid Kidwai has described as “a variety of short range, low yield nuclear weapons, also dubbed tactical nuclear weapons.”\(^{53}\) The first of these weapons to be made public is the 60 km range Nasr missile system that has been shown deployed on a truck mounted multi-tube launcher system that may have up to four missile launch tubes. It is assumed Pakistan plans to use such nuclear weapons on the battlefield to counter an Indian conventional attack on Pakistani territory.

In 2015, Mian and Nayyar wrote an article for the leading Indian current affairs journal Economic and Political Weekly exploring the history of Pakistani thinking about tactical use of nuclear weapons and challenging the justifications for the Nasr system.\(^{54}\) The article used a simple model of nuclear weapon effects on armored forces to show the limited utility of the use of low-yield tactical nuclear weapons. While such use of tactical nuclear weapons may not prove decisive on the battlefield, it may trigger escalation into a larger nuclear exchange that targets cities. As an alternative, the article proposes that Pakistan and India revive the idea first proposed by India in 1949 and 1950 of a No-War Agreement that would ban both support for cross-border militancy and military incursions across the border.

The South Asian security landscape has becoming increasingly more unstable and complex than can be captured by the India-Pakistan rivalry, however. The security situation is made more dangerous by a near civil war situation prevailing in Pakistan as Islamist militancy and ideology challenges the state and its institutions and society at large. This has implications for the security of nuclear weapons and materials in Pakistan.

In summer 2015, Hoodbhoy and Mian researched and wrote an essay “Securing Pakistan’s Nuclear Arsenal – The Threat from Within.” The essay is to appear in early 2016 in the

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52 Pervez Hoodbhoy, “Is third largest large enough?” Dawn, 29 August 2015.
volume *Nuclear Terrorism: Countering the Threat*, edited by Brecht Volders & Tom Sauer, as part of the Global Security Studies Series published by Routledge. The essay assesses the threat to Pakistan’s nuclear weapons and weapon-usable materials by focusing on how changing attitudes within the Pakistani military affect these dangers. It highlights in particular the polarization within Pakistan’s armed forces, including those charged with managing and guarding the nuclear arsenal and production complex, between national identity and institutional loyalty on the one hand and the rising appeal of radical Islam on the other. The scale of this polarization is evident in the reported cases of senior military officials found to have ties to religious extremist groups. It may take a fundamental reorientation of Pakistani society and politics to reduce these risks.

In spring 2015, Ramana and Mian wrote extensive updates on the state of India’s and Pakistan’s nuclear forces respectively for a volume *Assuring Destruction Forever*, a report documenting nuclear weapon modernization and maintenance activities around the world that is published by the Reaching Critical Will project of the Women’s International League for Peace and Freedom. Ramana’s contribution included an assessment of India’s nuclear missile and submarine programs as well as plans to develop and deploy a ballistic missile defense (BMD) system, fissile material production capacity and stockpiles, and the role of other countries in furthering India’s BMD program. Mian covered Pakistan’s ballistic missile systems and tactical battlefield weapons, nuclear weapon storage sites, fissile material production, the associated economic costs, as well as the role Pakistan has been playing in arms control negotiations.

In April 2015, Princeton University’s Center for International Security Studies hosted a delegation of six Members of Parliament from India. Mian briefed them about the state of nuclear weapons risks in Pakistan and India, and Ramana presented an overview of nuclear energy deployment around the world and the problems confronting nuclear power in India.

**Nuclear energy in South Asia**

Along with expanding their nuclear weapons programs, Pakistan and India have been building new nuclear power reactors and have announced ambitious plans for further increasing nuclear capacity over the next few decades.

In 2015, Hoodbhoy, Nayyar and Mian continued their efforts to inform the public and policy makers in Pakistan about the need to revisit the decision to build two Chinese-supplied 1100 MWe nuclear power reactors in Karachi city, home to nearly 20 million people – about one out of ten of all Pakistanis. The risks stem from both the reactor site and the unknown reliability of the reactor design. The campaign over the reactors has drawn international attention.

In October 2014, responding to public interest litigation to which Nayyar and Hoodbhoy were parties, the High Court of Sindh province halted construction on the reactors – the first

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time that a Pakistani court has halted a nuclear construction project. In late December 2014, after two months of hearings informed by technical arguments supplied by Mian, Nayyar and Hoodbhoy, the Sindh High Court ordered the Pakistan Atomic Energy Commission to prepare a new Environmental Impact Assessment and submit it for review and approval by the Sindh Environmental Protection Agency (SEPA). SEPA was ordered to hold a public hearing and invite public comment as part of the review process. This precedent setting decision offered the hope of imposing some degree of transparency and accountability on Pakistan’s nuclear power program.

In response to the court’s ruling, the Pakistan Atomic Energy Commission submitted a 2400 page long Environmental Impact Assessment report for the Karachi reactors covering the reactor site geology, earthquake and tsunami history, local ecology and population distribution, wind patterns, nuclear reactor safety features, and expected radioactivity releases during normal operation. The report claimed the reactors would pose no significant risk over their expected 60 year operating lifetime to the inhabitants of Karachi. Within days of receiving this report, SEPA accepted its findings. It is hard to imagine how a serious independent review of the Environmental Impact Assessment report could have been conducted in such short time.

Mian, Hoodbhoy and Nayyar pointed out some of the major shortcomings in the Environmental Impact Assessment report and shared them with civil society groups seeking to participate in the court mandated public hearing process. The report, for example, makes no mention of possible accidents at the spent fuel pools to be built at the reactor site. Radioactivity released in a spent fuel pool accident can be much larger than from a reactor accident. The actual public hearing process proved to be a farce, however, and construction on the reactors has resumed.57 Hoodbhoy and Nayyar have continued to work with civil society groups in Karachi to inform and mobilize public opinion on risk from the reactors through lectures and presence in the media, and written op-eds in Pakistani newspapers on the problems with nuclear energy and safety.58

Ramana and Nayyar completed and submitted to Science and Global Security their research on the potential impact of an accident at a tank holding liquid high-level waste (HLW) at the Kalpakkam Reprocessing Plant in southern India. After describing the different possibilities for chemical explosions to take place at a tank and rupture the tank as well as other physical barriers, they studied the atmospheric dispersion and fallout of fission products all over southern India. In an article in The Economic Times Ramana explained why reprocessing of spent fuel simply makes no sense from both an environmental and economic perspective, and that given the risk of accidents at reprocessing plants and associated facilities, India should stop separating plutonium.59

Ramana also wrote a series of articles explaining why fast breeder reactors fueled with plutonium will slow down India’s efforts to expand nuclear power, and more generally the inappropriateness of nuclear power as a solution to India’s energy needs or to meet greenhouse gas emission reduction goals. Along with former SGS visitor Dr. Suvrat Raju, an Indian physicist currently at the International Centre for Theoretical Sciences, Bangalore, Ramana wrote several articles about why importing nuclear reactors from France and the United States will result in high economic costs for Indian electricity customers and the safety risks that come from shielding reactor suppliers from liability for nuclear accidents.

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Strengthening Biological Security

One Health

Laura Kahn finished researching and writing her retitled book, *One Health and the Politics of Antimicrobial Resistance*, which will be published by Johns Hopkins University press in Spring 2016. Antibiotics are the foundation of modern medicine and public health, and for better or worse, of modern agriculture as well.

Historically, vancomycin had been the drug of last resort against resistant enterococci, such as *Enterococcus faecium*. However, the rise of vancomycin-resistance *Enterococcus faecium* (VRE) in the late 1990’s diminished its usefulness. The presence of VRE in livestock in England and Germany drove the European Union to ban the use of avoparcin and other antibiotic growth promoting agents in livestock. Avoparcin, a growth promoting antibiotic, was chemically related to vancomycin and presumed to be the cause for the growing problem of VRE. Surveillance studies of VRE on farms and in communities found it colonizing the guts of livestock and healthy people. Many assumed that the use of avoparcin on farms contributed to the rise of VRE in hospitals as well.

Kahn analyzed VRE bacteremia data in European hospitals over a ten-year period (2003-2013). Theoretically, the ban of avoparcin should have led to a decrease in VRE bacteremias in all European hospitals, but that is not what was found. Some countries, such as France, the Netherlands, and Sweden, had consistently low rates of VRE. Other countries, such as Denmark, Belgium, Greece, and Ireland, demonstrated increases in VRE bacteremias. In other words, the ban had no apparent benefit on the rates of VRE bacteremias in hospitals. There was, however, a very strong correlation between hospital vancomycin use rates and VRE bacteremia rates.

In contrast to Europe, the United States never approved avoparcin as a growth promoting agent because of concerns about its potential carcinogenicity. As a result, the epidemiology of VRE in the U.S. has been different compared to Europe. VRE has not been a problem on farms or communities in the US, yet it has been epidemic in hospitals.

The advent of genomic sequencing and analyses yielded surprising findings to the VRE conundrum. VRE in livestock and in healthy people were found to be genetically distinct from VRE in hospitals. Instead, the genetic predecessors of hospital VRE were found in dogs. These findings could have profound implications in addressing antimicrobial resistance, since companion animals have been virtually ignored on this issue. The VRE findings might not be applicable to other foodborne pathogens such as *Salmonella*, *Campylobacter*, and *E. coli* whose genomes have yet to be analyzed. Kahn has been presenting these findings at national and international medical and veterinary medical conferences.
Biosecurity

Kahn continues to write online columns with the Bulletin of the Atomic Scientists. One column, in particular, generated considerable interest and was picked up by Slate: “The next epidemic brought to you by the US government.” Kahn discussed the controversial move of the Plum Island Animal Disease Center, which studies highly communicable diseases such as foot-and-mouth virus to Manhattan, Kansas to become the National Bio and Agro Defense Facility (NBAF) run by the Department of Homeland Security.

A risk analysis performed by a contractor hired by DHS originally found a 70 percent chance of a catastrophic release of the foot-and-mouth (FMD) virus over the fifty-year life of the facility. The major risk components were identified as human error and mechanical/software failures. DHS had the contractor do another risk assessment with the assumption that with proper training and engineering, such failures would rarely occur. They found much lower numbers and estimated a less than 1 in 10,000 chance of an FMD release. A first National Academy of Sciences (NAS) committee reviewed the original contractor’s risk analysis. A second NAS committee convened by DHS considered the revised assessment and concluded that it was technically inadequate in critical respects and insufficient for evaluating the risks associated with the proposed NBAF lab. However, DHS accepted the revised risk assessment and approved the building of the new lab in Kansas. Congress also approved moving forward despite the NAS committee’s report of a flawed risk assessment. If the FMD virus were to escape NBAF and establish itself in wildlife, then commercial production of livestock for export would end and result in billions of dollars of losses. Kahn has been working with concerned members of the first NAS committee and with grass roots residents of Manhattan, Kansas to bring these safety and security concerns to greater attention.

Chyba serves as a member of President Obama’s Council on Science and Technology (PCAST), and in 2015 continued his work within PCAST and the administration on biological security issues, especially with respect to the implications of advances in microbial and molecular biology on the potential for biological weapons use by a variety of actors.

Space Security

In 2014, Wang Ting worked on the Chinese anti-satellite (ASAT) program and its implications for nuclear strategic stability. China launched a suborbital rocket on May 13, 2013 that the Chinese Academy of Science stated was a scientific research mission. Wang calculated the trajectory of the test and found that a new type of rocket must have been used in the test. In addition, he argued based on publicly available data that the Chinese Academy of Science does not have enough funding to support such a project. He concluded that the test is most likely to be related to a high-altitude ASAT weapon. While there are few U.S. geosynchronous military satellites above Chinese territory, one of the satellites is an early warning satellite. If the U.S. early warning satellite were disabled and China reduced the radar cross section of its warheads, Wang found that the U.S. early warning radars might not be able to detect incoming Chinese ICBM warheads. Therefore, he argued, Chinese missiles could elude the U.S. missile defense system. Paralyzing U.S. early warning satellites might be viewed by China as a technical solution to deal with U.S. missile defense. However,
attacking early warning satellite might inadvertently cause nuclear escalation and nuclear exchange. Wang submitted this work for publication.

Wang also worked on the problem of space debris, also a long-standing interest of Chyba. The space debris problem is a classic example of the tragedy of the global commons, with short-term interests taking precedence over regard for the shared environment. Governments tried to solve this problem by establishing guidelines and codes of conduct. However, Wang’s research finds that, due to lack of economic incentive, the guidelines are not well executed. More important, as sensors are getting smaller the microsatellite business is booming, and the number of satellites launched each year significantly increases. Microsatellites, which usually do not have maneuver capability, therefore pose a growing hazard to the space environment. In a paper now published in *Science and Global Security*, Wang therefore proposed establishing a market-oriented system to deal with the space debris problem.

Finally, Wang worked on understanding the logic of deploying a national missile defense. Many Chinese believe the U.S. missile defense system is aimed at China and poses a significant threat to the Chinese nuclear force. At the same time, ground-based midcourse missile defense is considered unworkable by various scientists in the U.S., especially those in the arms control community. The test records of the national missile defense seem to support their concerns. Wang interviewed supporters and opponents of the U.S. missile defense system, in order to try to understand the logic behind missile defense and explain it to a Chinese audience, so that they could better understand the intention and “threat” of U.S. missile defense.

Chyba continues to conduct research and, through his PCAST role, work within the administration on a variety of issues of space policy and space security.
III. Fostering the Development of Independent Technical Expertise

A Worldwide Network

Since its founding in 1974, SGS has trained young researchers and students in nuclear arms control, disarmament and non-proliferation policy issues. A key element has been the effort to recruit and train technical post-doctoral researchers interested in working on security policy. SGS also brings more senior foreign scientists who are interested in security policy to Princeton for a summer, semester, or sabbatical year to deepen their expertise. As noted in the South Asia section above, SGS also has hosted one to two scientists from India, Pakistan or both, almost every summer since 1998.

Supported largely by a Macarthur Foundation grant for training the next generation of nuclear non-proliferation, arms control, and disarmament scientists, SGS hosted seven postdoctoral researchers in 2015:

- Ali Ahmad, Lebanon (PhD, Cambridge University, UK) arrived in October 2013 and worked on emerging nuclear power programs in the Middle East and on proliferation implications of molten-salt and small modular reactors. He also worked on how Iran’s Arak research reactor could be redesigned to reduce its plutonium production. In September 2015, he moved to Lebanon as a visiting scholar at the Issam Fares Institute for International Affairs and Public Policy at the American University in Beirut.
- Bernadette Cogswell, United States (PhD, Vanderbilt University) arrived in November 2014 and is exploring potential verification and safeguards applications of the detection of antineutrinos from nuclear reactors.
- Malte Göttsc, Germany (PhD, University of Hamburg) arrived in October 2015 and is working on nuclear warhead verification with Glaser. He is supported by the U.S. Department of Energy funded Consortium for Verification Technology.
- Michael Schoepnner, Germany (PhD from Roma Tre University, Italy) arrived in September 2014 and has been working on analyzing the detectability of clandestine underground nuclear tests and clandestine plutonium separation by detection respectively of radioactive xenon and krypton-85 in the atmosphere.
- Ryan Snyder, United States (PhD, University of Virginia) arrived in August 2014 and has been analyzing the technology and proliferation risks of the laser isotope enrichment that General Electric is trying to commercialize in the United States, and also on developing ideas for a multinational uranium enrichment regime for the Middle East.
- Wang Ting, China (PhD Beijing University of Aeronautics and Astronautics, China) arrived in August 2013 and worked on a proposal to establish a liability and insurance regime able to mitigate the risks from space debris caused by collisions between satellites. He also studied what may have been a Chinese test of capabilities that could be used to destroy a U.S. early-warning satellite and worked to understand the politics behind the U.S. ballistic missile defense program. He returned to China in October 2015.
• Yan Jie, China (PhD, University of Science and Technology, China) arrived in May 2014 and worked with Glaser on nuclear warhead verification. He returned in December 2015 to his position at the Institute of Nuclear Physics and Chemistry, Academy of Engineering Physics of China.

In 2015, SGS also hosted Tadahiro Katsuta, an Associate Professor at Meiji University in Tokyo, Japan, as a Visiting Fellow. He will be with the Program until April 2016. Katsuta is an official member of the study team for Japan’s Nuclear Regulation Authority charged with developing new regulatory requirements for commercial nuclear power reactors, and for nuclear fuel facilities, research reactors, and nuclear waste storage/disposal facilities. He is working on Japan’s spent fuel management problems as well as studying the Fukushima Dai-ichi nuclear power plant accident of March 2011 and an assessment of Japan’s new nuclear regulatory standards. Katsuta previously spent the 2007-2008 academic year at SGS on the prestigious Abe Fellowship, supported by the Japan Foundation Center for Global Partnership and the Social Science Research Council.

More detailed bios are available in Appendix A and information on published papers and talks is in Appendix B.

**IPFM Website and Blog**

IPFM’s website, www.fissilematerials.org, is now established as a global resource on matters related to fissile materials. It hosts IPFM publications, a library of historical and contemporary documents, and regularly updated global lists of uranium enrichment and reprocessing facilities and HEU-fueled research reactors. The associated blog, managed from Geneva by Pavel Podvig, reports and records important developments related to fissile material production, stockpiles and disposal for the expert community, policy makers and the public.

As of the end of 2015, the website was getting about 2000 visits a month, which is a good result for a specialized web resource, and visit rates have stayed roughly constantly at this level over the past few years. About 33 percent of visitors to the IPFM website are from the United States. Other countries in the top-ten list include China, India, the United Kingdom, Japan, Germany, France, Pakistan, Austria, France, and Russia. Among the top identified visitors are universities in the United States, Europe, and Asia, the International Atomic Energy Agency, the U.S. Department of Energy and its laboratories (Pacific Northwest, Lawrence Livermore, Oak Ridge, Argonne), the U.S. State Department, Nuclear Regulatory Commission, Department of Defense, Government Accountability Office, Senate and House of Representatives. Institutional visitors from outside of the United States include France’s Commissariat à l’Énergie Atomique, AREVA, and the United Nations.

IPFM reports, briefings and files from the library available on the website were downloaded about 78,000 times in 2015 (256,000 since re-launch of the site in February 2012). The table below lists the most popular IPFM publications by number of downloads. The sustained interest in some of IPFM’s older publications is significant. The two IPFM research reports issued in 2015 were each downloaded over 1000 times.
Table 1. Top downloaded IPFM publications in 2015

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<th>Publication</th>
<th>Downloads (2015)</th>
<th>Downloads (total)</th>
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<td>Fast Breeder Reactor Programs: History and Status (2010)</td>
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<td>GFMR 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament (2013)</td>
<td>5,960</td>
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<td>Managing Spent Fuel from Nuclear Power Reactors. Experience and Lessons from Around the World (2011)</td>
<td>4,498</td>
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<tr>
<td>Ending reprocessing in Japan: An alternative approach to managing Japan's spent nuclear fuel and separated plutonium (2013)</td>
<td>3,976</td>
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<td>Country Perspectives on the Challenges to Nuclear Disarmament (2010)</td>
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<td>Spent Nuclear Fuel Reprocessing in France (2008)</td>
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<td>Spent Fuel from Nuclear Power Reactors. Overview of a New Study by the International Panel on Fissile Materials (2011)</td>
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<td>GFMR 2009: A Path to Nuclear Disarmament (2009)</td>
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<td>GFMR 2010: Balancing the Books: Production and Stocks (2010)</td>
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<td>Global Fissile Material Report 2011 (2011)</td>
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<td>The Uncertain Future of Nuclear Energy (2010)</td>
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<td>GFMR 2015 Presentation</td>
<td>1,475</td>
<td>1,504</td>
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<td>Alternatives to MOX. Direct-disposal options for stockpiles of separated plutonium (2015)</td>
<td>1,190</td>
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<td>Fissile Material Controls in the Middle East: Steps toward a Middle East Zone Free of Nuclear Weapons and all other Weapons of Mass Destruction (2013)</td>
<td>975</td>
<td>2,699</td>
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</table>

**Science & Global Security – the Journal**

SGS has been the editorial home of the journal *Science & Global Security* since the journal was founded in 1989 as a way for technical arms control experts in the United States and Soviet Union to communicate with other and reach a shared understanding. The journal, which has three issues each year online which are combined into one annual printed issue, publishes peer-reviewed scientific and technical studies to support international security, arms control, disarmament, and nonproliferation policy. The journal now covers nuclear, biological, chemical, space and cyber technologies and programs and related security issues. All issues of the journal are translated into Russian.
The journal was edited by Harold Feiveson until 2011, when Alexander Glaser, Zia Mian and Pavel Podvig took over as co-editors. Since 2014, Sébastien Philippe, an SGS PhD student, has served as a part-time Editorial Assistant.

In 2013, a new dedicated journal website, www.scienceandglobalsecurity.org, was launched as a way to bring greater attention to the work published in it. It also hosts a free regularly updated archive of all the papers published in the journal since its first issue, except for those published in the past year. It has attracted an increasing number of visitors and downloads of papers. During 2015, the website registered about 9000 visitors (about 7000 unique visitors) accessing more than 21,000 pages. In 2015, users in the United States accounted for about 27 percent of all visitors. Russia was a close second with 21% of all visitors. Other countries in the list of top visitors include Germany, Ukraine, the United Kingdom, Brazil, India, Hungary, China, and Italy. Most of the visits, however, are direct downloads, which are counted separately.

The site has been redesigned to make papers in the journal archive available for indexing by search engines, such as Google Scholar. As a result, there was a significant increase in the number of downloads – the articles in the journal archive were downloaded about 68,500 times in 2015, as compared to 45,500 downloads in 2014 and 33,000 in 2013.

**Teaching and Mentoring**

SGS faculty and researchers teach undergraduate and graduate security studies courses and policy workshops and also supervise undergraduate senior theses. In 2015, the undergraduate courses taught were:

- “Living in a Nuclear-Armed World” (a freshman seminar)
- “Science and Global Security: From Nuclear Weapons to Cyberwarfare” (jointly offered by the Mechanical Engineering Department and the Woodrow Wilson School)
- “Science and Technology of Nuclear Energy: Fission and Fusion” (jointly offered by the departments of Astrophysics, Mechanical Engineering, and Physics).

The graduate courses were “Weapons of Mass Destruction and International Security,” as well as a half-semester graduate course “The Future of Nuclear Energy after Fukushima,” and 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 International Security and Science, Technology and Environmental Policy (STEP) clusters has made it possible for students with science or engineering undergraduate or master’s degrees to pursue doctoral studies with SGS faculty. To provide opportunities for faculty and students to work together on technical nuclear policy issues, Glaser has established a Nuclear Futures Laboratory in the Princeton Engineering School.

In 2015, we have six Princeton PhD students in our program:
• Tamara Patton, a first year PhD student in the STEP program in the Woodrow Wilson School.
• Ben Reimhold, a first year PhD student in Mechanical and Aerospace Engineering.
• Sébastien Philippe, a fourth-year PhD student in Mechanical and Aerospace Engineering. Philippe is working with Glaser on a thesis involving experimental development and demonstration of the Princeton zero-knowledge approach to nuclear warhead verification.
• Julien de Troullioud de Lanversin, a second-year student in Mechanical and Aerospace Engineering, planning to work with Glaser on nuclear warhead verification.
• Caroline S. Reilly, a sixth-year PhD student in Security Studies in the Woodrow Wilson School, working with Chyba on the processes by which nuclear-armed adversaries perceive and respond to conditions of mutual vulnerability. This has implications for the strategic stability of the U.S.-China relationship. Reilly spent part of 2015 at the RAND Corporation in Washington DC.
• Mark Walker, a fourth-year PhD student in the STEP program in the Woodrow Wilson School, is working with Glaser on nuclear transparency and verification. Walker spent part of 2015 at the IAEA as part of a group doing R&D for the Department of Safeguards.

During the fall of 2015 the Program also hosted as a Visiting Student Research Collaborator Moritz Kütt, a PhD student at the University of Darmstadt in Germany. Kütt will spent a year working under the supervision of Alexander Glaser and Zia Mian on a project to explore and develop criteria for Open Source software applications in nuclear non-proliferation, arms control and disarmament and contributed to other research projects at the Program.
APPENDIX A

Personnel

January 1, 2014 – December 31, 2014

Ali Ahmad is a researcher in nuclear energy policy at Princeton University's Program on Science and Global Security. He is also an Associated Researcher at Princeton’s Nuclear Futures Laboratory and the Issam Fares Institute for Public Policy and International Affairs at the American University of Beirut. Ali’s work covers nuclear technology and fuel cycle assessments, economics of nuclear energy 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 contributions to the field of nuclear arms control and de-alerting.

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 includes nuclear weapons arms control, biological security, and space policy issues. He currently serves on President Obama’s Council of Advisors on Science and Technology (PCAST).

Bernadette Cogswell (Postdoctoral Research Associate) joined the Program mid-Fall 2014. Her work examines nuclear reactor and nuclear fuel cycle safeguards, including an assessment of the viability of antineutrino monitoring as a safeguards tool, the technical challenges for arms control verification and the feasibility of nuclear energy for developing nations. She has a PhD in theoretical particle physics from Vanderbilt University, where her research focused on neutrino oscillation phenomenology.

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 co-editor of Science & Global Security and co-chair of IPFM.

Malte Götsche joined the Program on Science and Global Security in October 2015 as a post-doctoral researcher and a fellow of the Consortium for Verification Technology. He is interested in technical and policy issues of verifying future nuclear arms control and disarmament agreements. At Princeton, he is working on warhead authentication based on nuclear measurements and overarching verification concepts and schemes. Malte holds a doctoral degree in physics from the University of Hamburg, where he worked as a research assistant at the Carl Friedrich von Weizsäcker-Centre for Science and Peace Research from 2012 until 2015. Earlier, he had been a visiting scholar at the Monterey Institute of International Studies. Malte is affiliated with the Interdisciplinary Research Group on Disarmament, Arms Control and Risk Technologies of the Institute for Peace Research and Security Policy in Hamburg.

Robert J. Goldston is a leading researcher in plasma physics and fusion energy, and was director of the Princeton Plasma Physics Laboratory (PPPL), 1997 – 2009. Goldston has collaborated with SGS staff on a number of research topics since 2009. He contributed a section on Fusion Energy to a chapter on Nuclear Energy prepared by Frank von Hippel for the IIASA Global Energy Assessment. Goldston and Alex Glaser published on the potential proliferation risks associated with magnetic fusion energy, and the role of safeguards in minimizing these risks. Goldston chaired an IAEA Consultative Group on this topic. Goldston and Glaser also published on proliferation risks specifically associated with Inertial Fusion Energy; their perspectives are reflected in the NAS Panel Report on Inertial Fusion Energy. Most recently Goldston has collaborated with Glaser and Boaz Barak of Microsoft Research, New England, on a “Zero-Knowledge Protocol” for warhead verification as an element of arms control. They received a “V Fund” grant from the State Department, and a larger grant from the National Nuclear Security Administration as part of a new national Center for Verification Technology led by the University of Michigan. Goldston and Glaser are constructing facilities to test this technique experimentally at PPPL.

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. Her new book, One Health and the Politics of Antimicrobial Resistance, will be published by Johns Hopkins University press in Spring 2016
Zia Mian (Research Scientist and Director of SGS’s Project on Peace and Security in South Asia) joined SGS in September 1997. He is a co-editor of the journal Science & Global Security and as of 2015 co-Chair of the International Panel on Fissile Materials. 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. In 2014, he was awarded the Linus Pauling Legacy Award “for his accomplishments as a scientist and as a peace activist in contributing to the global effort for nuclear disarmament and for a more peaceful world.”

Caroline R. Milne is a doctoral candidate in Security Studies at the Woodrow Wilson School, having returned after a year-long Stanton Nuclear Security Fellowship at the RAND Corporation, where she specialized in U.S. and Chinese perceptions of mutual nuclear vulnerability and strategic stability. Under the guidance of advisor Christopher Chyba she is completing her dissertation, which examines how nuclear-armed adversaries understand and address the strategic balance, particularly in the cases of the Cold War superpowers and in the contemporary U.S.-China relationship. Caroline has a B.S. in aerospace engineering from MIT and a M.A. from the War Studies Department at King’s College London.

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-U.S. relations and elimination of weapons of mass destruction in the Middle East. His most recent books are: The Iranian Nuclear Crisis: A Memoir (2012) and Iran and the United States: An Insider’s view on the Failed Past and the Road to Peace (2014).

Tamara Patton is a PhD candidate in Science, Technology and Environmental Policy at the Woodrow Wilson School of Public and International Affairs. Her research examines systems and technologies for verifying future nuclear arms control and disarmament agreements. She works with virtual reality environments to design and simulate structure and protocol options for verifying nuclear weapon and fissile material reductions. Prior to coming to Princeton, she was a researcher at the Vienna Center for Disarmament and Non-Proliferation (2014-2015) and at the Stockholm International Peace Research Institute (2012-2013). She has an MA in nonproliferation studies from the Middlebury Institute of International Studies and a BA in international studies from the University of Washington.

Sébastien Philippe is a doctoral student at Princeton University’s Department of Mechanical and Aerospace Engineering. His research focuses on innovative verification approaches and technologies to support future arms control treaties, including the practical implementation of zero-knowledge protocols for nuclear weapons authentication. Sébastien is a member of Princeton’s Nuclear Futures Laboratory and affiliated with SGS. Since the spring of 2014, he is editorial assistant of the journal Science and Global Security. Before joining Princeton in 2012, Sébastien worked for two years in the French Ministry of Defense. He holds an M.A.
from Princeton University (2014) and a M.Sc. degree in engineering from France’s National Institute of Applied Sciences in Lyon (2010).

**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 a physics degree from MIPT (1988) 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 shares the Indian seat on the IPFM with Professor Rajaraman.

**Michael Schoepnner** (Postdoctoral Research Associate) joined the Program on Science and Global Security in Fall 2014. His research focuses on atmospheric transport modeling of radioactive noble gases for the verification of nuclear arms control treaties. Michael has Master’s degrees from the University of Muenster (Germany) and the University of Hamburg (Germany), and a PhD from the Roma Tre University (Italy). Before joining the Program he was working as a consultant for the Preparatory Commission of the Comprehensive Nuclear-Test-Ban Treaty Organization in Vienna (Austria).

**Ryan Snyder** (Postdoctoral Research Associate) joined the Program on Science and Global Security in August 2014. He is working on technical and policy questions related to the proliferation risk from the use of laser isotope separation for uranium enrichment and on improving international safeguards on the nuclear fuel cycle, and the future of nuclear power. He was previously a Fellow for Energy Studies at the Federation of American Scientists and an adjunct lecturer in physics at American University, both in Washington D.C. In graduate school he worked at the Thomas Jefferson National Accelerator Facility as part of a collaboration that used parity-violating electron scattering to measure the strange-quark contribution to the structure of the nucleon. He received a B.A. in physics from Kenyon College and a Ph.D. in nuclear physics from the University of Virginia.

**Julien de Trouillioud de Lanversin** joined the SGS’s Nuclear Futures Laboratory in 2014 as a Ph.D. candidate in the Department of Mechanical and Aerospace Engineering. He aims to work on the proliferation resistance feature of new concepts of nuclear reactors. Before joining Princeton, Julien received a Master degree in 2014 from the University of Tsinghua, Beijing, in the field of nuclear engineering. In his thesis work, Julien developed innovative ways to solve the time dependent depletion equation with mathematics methods borrowed from quantum physics. The same year, he also graduated from the French Engineering School Centrale Marseille (equivalent of a Master degree).
Frank von Hippel (Senior Research Physicist and Professor of Public and International Affairs Emeritus) and member of the International Panel on Fissile Materials, a nuclear physicist, co-founded the Program on Science and Global Security and the International Panel on Fissile Material. 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 fourth-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. He is a 2011 recipient of the Barry M. Goldwater Scholarship. His research involves the application of technical and political measures to strengthening the nuclear safeguards capabilities of the International Atomic Energy Agency. He holds an M.A. in Public Affairs from Princeton University (2014) and a B.Sc. in Nuclear Engineering from the University of Tennessee, Knoxville (2012).

Wang Ting joined SGS in 2013, working on space debris problems and 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.

Yan Jie (Post-Doctoral Researcher) joined SGS in June 2014, working on using the zero-knowledge approach to arms control inspection and verification problems. Prior to joining Princeton, he was an associate professor at the Institute of Nuclear Physics and Chemistry, China Academy of Engineering Physics. His work was focused on neutronics physics and their applications to military and homeland security. He received a PhD in particle and nuclear physics from the University of Science and Technology of China.

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 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. In 2014, he was a member of the United Nation’s Secretary General’s Advisory Board on Disarmament Matters.
**Tadahiro Katsuta** (Visiting Fellow) is spending a year with the Program beginning April, 2015. He also spent the 2007-2008 academic year at the Program on the prestigious Abe Fellowship, supported by the Japan Foundation Center for Global Partnership and the Social Science Research Council. He is currently researching Japan’s spent fuel management problems as well as studying the Fukushima Dai-ichi nuclear power plant accident and is following the new regulation standard focusing on the technical and political aspects. Katsuta is an official member of the study team for the New Regulatory Requirements for Commercial Nuclear Power Reactors, and for Nuclear Fuel Facilities, Research Reactors, and Nuclear Waste Storage/Disposal Facilities by the Nuclear Regulation Authority (NRA). From 2008-2009, he conducted research on multilateral nuclear fuel cycle systems as a Visiting Fellow at PSGS. From 2006-2008, he conducted research on the separated plutonium problem caused by Rokkasho reprocessing plant at the University of Tokyo. From 1999-2005 he worked at Citizens Nuclear Information Center (CNIC) in Tokyo as a researcher.

**Moritz Kütt** has been a Visiting Student Research Collaborator at the Program on Science and Global Security and the Nuclear Futures lab since October 2015. He is a PhD candidate in the Physics Department at Technische Universität Darmstadt, Germany. He is doing research on the role of Open Source Software in the field of nuclear disarmament and non-proliferation. Before starting his PhD, he received a master’s degree in Physics from and a BA in Political Science from the Technische Universität Darmstadt.

**Abdul H. 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. In 2014, Mashal books, a non-profit publisher based in Lahore, published the Urdu volume *Taqat ka Sarab* (The Illusion of Power) edited by Nayyar; the book is the most extensive collection of articles on the nuclear dangers in the region available in Pakistan’s national language.
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.

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 10 years. She provides administrative support to the Program, the director, faculty, and program manager.
APPENDIX B

Publications and Reports

January 1, 2015 – December 31, 2015

Ali Ahmad


Iran and multinational enrichment in the Middle East, *Bulletin of the Atomic Scientists*, 72, no. 1 (with Ryan Snyder)

Saudi Arabia must not focus on nuclear power, *Gulf News*, 26 June 2015 (with M.V. Ramana)

With the Iran deal, the devil is in the details, *The Daily Star*, 29 April 2015

Tehran may benefit from a nuclear freeze, *The Daily Star*, 20 March 2015

Jordan’s bet on nuclear power is risky, *The Daily Star*, 27 February 2015

Bruce G. Blair


Christopher F. Chyba


President’s Council of Advisors on Science and Technology (J. P. Holdren, E. Lander, W. Press, M. Savitz, W. Austin, R. Bierbaum, C. Cassel, C. Chyba, S. J. Gates, M. Gorenberg, S. L. Graham, M. McQuade, C. Mirkin, M. Molina, C. Mundie, E. Penhoet, B. Schaal, E.


Harold Feiveson

**The Iran Deal Explained**, *Dissent*, 12 August 2015

Alexander Glaser

**Building on the Iran Deal: Steps Toward a Middle Eastern Nuclear-Weapon-Free Zone**, *Arms Control Today*, December 2015 (with Z. Mian, S. H. Mousavian, and F. von Hippel)


**Designing Protocols for Nuclear Warhead Verification**, *Proceedings of the 56th Annual INMM Meeting*, 2015 (with S. Philippe and B. Barak)

**Virtual Gamma-ray Spectrometry for Template-Matching Nuclear Warhead Verification**, *Proceedings of the 56th Annual INMM Meeting*, 2015 (with J. Schirm)

**Detecting Clandestine Plutonium Separation Activities with Krypton-85**, *Proceedings of the 56th Annual INMM Meeting*, 2015 (with M. Schöppner and M. Walker)

**Leveraging the Wisdom of the Crowd: Hardware and Software Challenges for Nuclear Disarmament Verification**, *Proceedings of the 56th Annual INMM Meeting*, 2015 (with M. Kütt and S. Philippe)

Small Modular Reactors: A Window on Nuclear Energy, Energy Technology Distillate, Andlinger Center for Energy and the Environment, Princeton University, June 2015 (with M. V. Ramana, A. Ahmad and R. Socolow)


Education and Outreach Activities Within the Consortium for Verification Technology, *Proceedings of the 56th Annual INMM Meeting*, 2015 (with S. D. Clarke et al.)


Robert J. Goldston


Pervez Hoodbhoy

Obama’s N-mission to India, *Dawn*, 31 January 2015

Let’s Go Nuclear — Safely, *Dawn*, 14 March 2015
Pakistan, the Saudis’ Indispensable Nuclear Partner, *New York Times*, 21 April 2015

Is Third Largest Large Enough? *Dawn*, 29 August 2015

Laura Kahn


If We Can’t Stop measles, How Will We Stop a Pandemic? *Bulletin of the Atomic Scientists*, 15 April 2015


Zia Mian


**Pakistan and the Nasr Missile**, *Economic and Political Weekly*, 26 September 2015 (with A.H. Nayyar)

**Building on the Iran Deal: Steps toward a Middle Eastern Nuclear-Weapon-Free Zone**, *Arms Control Today*, December 2015 (with Alexander Glaser, Seyed Hossein Mousavian, and Frank von Hippel)


**Caroline Milne**

**Bring Up the Bombs: Nuclear weapons should be on the U.S.-China summit agenda**, *U.S. News & World Report*, 23 September 2015

**Seyed Hossein Mousavian**

**What's holding up Iran nuclear deal?** *Al Monitor*, 7 January 2015

Extremism, Terrorism Ultimate Winners of Charlie Hebdo Episode, IRNA, 24 January 2015


**US and Seven Wrong Strategies in Diplomacy with Iran**, *Iran Review*, 31 January 2015

**The Iran nuclear dilemma: the peaceful use of nuclear energy and the NPT’s main objectives** in Harald Müller and Daniel Müller, eds., *WMD Arms Control in the Middle East: Prospects, Obstacles and Options*, Ashgate Publishing, 2015

**Iran ready for a nuclear deal: Column**, *USA Today*, 6 February 2015

36 years after the revolution, where is Iran now? *Al Monitor*, 11 February 2015

**Would Iran deal set new nuclear proliferation standard?** *Al Monitor*, 22 February 2015


**On Iran deal, Republicans cut off their nose to spite their face**, *Al Monitor*, 11 March 2015

**Seventeen points to know about Netanyahu**, *Gulf News*, 16 March 2015

**It is crucial that Iran and the US cooperate**, *El Pais*, 17 March 2015

America’s Middle East Challenge, *Cairo Review of Global Affairs*, 6 April 2015 (with Mehrdad Saberi)

The road to peace between Iran and the West, *El Pais*, 8 April 2015

After nuclear deal, what's next for Iran? *Al Monitor*, 14 April 2015


Building confidence, implications of the nuclear deal with Iran, *Security Times*, 1 June 2015

How do we solve the Iran talks' verification dilemma? *Al Monitor*, 6 June 2015


How to reach an agreement with Iran, *El Pais*, 2 July 2015


Together, Iran and the United States can shape the Middle East's future, *Telegraph*, 14 July 2015

If Congress Rejects the Iran Deal, It Would Be a Historic Blunder, *The Huffington Post*, August 2015

A rejection of the nuclear deal could lead to radicalism in Iran, *The Washington Post*, 28 August 2015

What Obama should say to King Salman during his visit, *Al Monitor*, 4 September 2015

It's Time for Republicans to Abandon Their Short-Sighted Approach to Iran, *The Huffington Post*, 14 September 2015

Should Congress Approve the Iran Deal? *Foreign Affairs*, 7 September 2015

Why Iran Doesn't Trust America -- And What Can Be Done to Change That, *The Huffington Post*, 5 October 2015


Will Iran's nuclear diplomacy lead to regional solutions? *Al Monitor*, 3 November 2015

To Solve the Syria Crisis, We Need to Overcome These Three Obstacles, *The Huffington Post*, 7 December 2015


Una estrategia sensate contra el ISIS, *El Pais*, 18 December 2015

Targeting Muslims Is the Real Threat to Peace, *The Huffington Post*, 29 December 2015

**Abdul Nayyar**

Pakistan and the Nasr Missile: Searching for a Method in the Madness, *Economic and Political Weekly*, 50, no.39, 26 September 2015 (with Zia Mian)

Karachi Nuclear Reactors: The Environmental Watchdog That Did Not Bark, *China Dialogue*, 7 September 2015 (with Zia Mian)

Caution Required, *Dawn*, 10 March 2015

**Pavel Podvig**


Russia, Strategic Stability, and Nuclear Weapons, in George P. Shultz and James E. Goodby, eds., *The War That Must Never Be Fought: Resolving the Nuclear Dilemma*, Hoover Institution Press, Stanford University, California 2015

Russia Tests Hypersonic Glide Vehicle, (with Alexander Stukalin) *Jane's Intelligence Review*, 4 June 2015


**M.V. Ramana**


Nuclear Deal no Cause for Celebration, *Hindu*, 31 January 2015 (with Suverat Raju)


Landscape in the Gulf: Strategic Implications (with Ali Ahmad)

Profitability without accountability, Hindu, 16 February 2015 (with Suvrat Raju)

Negligence, Capture, and Dependence: Safety Regulation of the Design of India’s Prototype Fast Breeder Reactor, Journal of Risk Research, 18, no. 8, 2015 (with Ashwin Kumar)


Is Nuclear the Answer to India’s Energy Crisis? SciDev.net, 20 April 2015

Saudi Arabia’s Expensive Quest for Nuclear Power, Nuclear Monitor, April 2015 (with Ali Ahmad)

Betting on the Wrong Horse: Fast Reactors and Climate Change, Mausam, April-June, 2015, reprinted in Nuclear Monitor, December 2015


No Big Deal, Hindu Business Line, 1 May 2015 (with Suvrat Raju)


Saudi Arabia Must not Focus on Nuclear Power, Gulf News, 25 June 2015 (with Ali Ahmad)


Looking Back, Looking Ahead: Plutonium Separation From Power Reactors, Nuclear Intelligence Weekly, 14 August 2015 (with Frank von Hippel)

Lesson for India: Why Reprocessing of Spent Fuel from Nuclear Reactors Makes Little Sense, Economic Times, 23 August 2015

An End to Reprocessing, Nuclear Monitor, 27 August 2015


*Ahead of Paris, An Unfavorable Climate for Nuclear?* *Nuclear Intelligence Weekly*, 20 November 2015

*The Strange Love for Nuclear Energy*, *Hindu*, 17 December 2015 (with Suvrat Raju)

*A False Hope*, *Bulletin of the Atomic Scientists Online*, December 2015


*Moving Nuclear Reactors Inland is a Bad Idea*, *Chinadialogue.net*, 11 January 2016 (with Amy King)


*Scrambling to Build a Nuclear Middle East*, *Bulletin of the Atomic Scientists*, 72, no. 1, 2016 (with Zia Mian)

**Michael Schoeppner**

*How to Improve the Nuclear Test Monitoring System*, *Bulletin of the Atomic Scientist*, February 2015 (with Ulrich Kuehn)

*Detecting Clandestine Plutonium Separation Activities with Krypton-85*, *Proceedings of the 56th Annual INMM Meeting*, 2015 (with Alexander Glaser and Mark Walker)

*Detecting Undeclared Plutonium Production: Standoff Monitoring of Nuclear Reprocessing Plants*, *Proceedings of the 56th Annual INMM Meeting*, 2015 (with Frank von Hippel).
Frank von Hippel


Overcoming the challenge of disposing of separated plutonium, *Disarmament Review*, Electronic Journal of Japan Association of Disarmament Studies, 6, no. 6, November 2015, pp. 13-18

Direct disposal is Better Solution for South Carolina’s Plutonium Problem, *Augusta Chronicle*, 24 October 2015 (with Edwin Lyman)


Direct disposal of excess plutonium, *Proceedings of the 56th Annual INMM Meeting*, 2015


A Disarmament Agenda, interview with *Physics Today*, June 2015, pp. 26-29 (with Alex Glaser and Zia Mian)


After the Iran Deal: Multinational Enrichment, *Science*, 348, no. 6241, 19 June 2015, pp. 1320-1322 (with Alex Glaser and Zia Mian)

Alternatives to MOX International Panel on Fissile Materials, Princeton, July 2015 (with Gordon MacKerron)

Scientist in the Public Interest (interview), *Bulletin of the Atomic Scientists*, 71 no. 1, January 2015

Wang Ting


Yan Jie


# APPENDIX C

## Lectures, Talks, Workshops

January 1, 2015 – December 31, 2015

### Ali Ahmad

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
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<tbody>
<tr>
<td>May 22, 2015</td>
<td>Economics of Nuclear Energy for the Middle East</td>
<td>American University of Beirut, Beirut, Lebanon</td>
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### Bruce G. Blair

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<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
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<tbody>
<tr>
<td>March 28-30, 2015</td>
<td>Organizer, Conference on Nuclear Risk Reduction; presentation of report findings and recommendations</td>
<td>Global Zero Commission on Nuclear Risk Reduction, Athens, Greece</td>
</tr>
<tr>
<td>April 7, 2015</td>
<td>Class Lecture</td>
<td>Class of Prof. Harold Feiveson, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>April 16, 2015</td>
<td>Plenary Meeting of Secretary of State’s International Security Advisory Board</td>
<td>State Department, Washington, D.C.</td>
</tr>
<tr>
<td>April 19, 2015</td>
<td>Introduction and Q&amp;A</td>
<td>Screening of “Countdown to Zero,” Princeton Public Library, Princeton, New Jersey</td>
</tr>
<tr>
<td>May 13, 2015</td>
<td>Introduction and Q&amp;A</td>
<td>Screening of “Countdown to Zero,” United Nations NPT Review Conference, UN Headquarters, New York City</td>
</tr>
<tr>
<td>June 15, 2015</td>
<td>“Regulating and Verifying Nuclear Postures”</td>
<td>Princeton-China Academy of Engineering Physics Workshop on Verification Technologies, Beijing, China</td>
</tr>
<tr>
<td>June 24, 2015</td>
<td>Plenary Meeting of Secretary of State’s International Security Advisory Board</td>
<td>State Department, Washington, D.C.</td>
</tr>
<tr>
<td>June 30, 2015</td>
<td>“Nuclear Abolition”</td>
<td>IGCC Public Policy and Nuclear Threats Boot Camp, Institute on Global Conflict and Cooperation, University of California San Diego, San Diego, CA</td>
</tr>
<tr>
<td>August 3, 2015</td>
<td>Plenary Meeting of Secretary of State’s International Security Advisory Board</td>
<td>State Department, Washington, D.C.</td>
</tr>
<tr>
<td>August 9, 2015</td>
<td>Address at Rally</td>
<td>Global Zero “Bike Around the Bomb” event, Washington, D.C.</td>
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<td>Organization/Occasion</td>
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<tr>
<td>September 14, 2015</td>
<td>Working Group Meeting of Secretary of State’s International Security Advisory Board</td>
<td>State Department, Washington, D.C.</td>
</tr>
<tr>
<td>September 15, 2015</td>
<td>Plenary Meeting of Secretary of State’s International Security Advisory Board</td>
<td>State Department, Washington, D.C.</td>
</tr>
<tr>
<td>October 19, 2015</td>
<td>“Risks of Nuclear Weapons Use”</td>
<td>STEP Seminar, Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>October 28, 2015</td>
<td>Panel Member, “Seconds to Stop the Final Countdown: the Cuba Missile Crisis in Okinawa</td>
<td>UN General Assembly First Committee Panel Presentation, UN Headquarters, New York City</td>
</tr>
<tr>
<td>November 1, 2015</td>
<td>Chair, Plenary Session: “Humanitarian Impacts of Nuclear Weapons”</td>
<td>61st Pugwash Conference on Science and World Affairs, Nagasaki University, Nagasaki, Japan</td>
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**Christopher F. Chyba**

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<tr>
<th>Date</th>
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<th>Organization/Occasion</th>
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<tbody>
<tr>
<td>January 8, 2015</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
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<tr>
<td>March 26-27, 2015</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 16, 2015</td>
<td>Speaker, West Chester University, 18th Annual Physics Awards Ceremony and Colloquium: Title “Oceans in the Solar System”</td>
<td>West Chester University, West Chester, PA</td>
</tr>
<tr>
<td>May 13-14, 2015</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
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<tr>
<td>July 12-14, 2015</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
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<tr>
<td>September 16-18, 2015</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
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<tr>
<td>November 18-20, 2015</td>
<td>President’s Council of Advisors on Science and Technology (PCAST)</td>
<td>National Academy of Sciences, Washington, DC</td>
</tr>
<tr>
<td>December 2-4, 2015</td>
<td>President’s Council of Advisors on Science and Technology (PCAST) - Biodefense Workshop</td>
<td>National Academy of Sciences, Washington, DC</td>
</tr>
<tr>
<td>December 10, 2015</td>
<td>Participant, Nuclear Verification At Low Numbers Workshop</td>
<td>Princeton University, E-Quad, Princeton, NJ</td>
</tr>
<tr>
<td>December 10, 2015</td>
<td>Speaker, Center of Theological Inquiry Title “Astrobiology and Society”</td>
<td>Center of Theological Inquiry, Princeton, NJ</td>
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### Bernadette Cogswell

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<tr>
<th>Date</th>
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<th>Organization/Occasion</th>
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<tbody>
<tr>
<td>January 21, 2015</td>
<td>Symmetry, hierarchy, and an alternative paradigm for analyzing neutrino oscillations</td>
<td>Center for Neutrino Physics, Virginia Tech, USA</td>
</tr>
<tr>
<td>May 6, 2015</td>
<td>Antineutrino technology and fissile materials</td>
<td>International Panel on Fissile Materials Annual Meeting, Princeton, USA</td>
</tr>
<tr>
<td>June 15-16, 2015</td>
<td>Antineutrino monitoring of nuclear reactors</td>
<td>PVTS-SGS Workshop on Verification Technologies, Beijing, China</td>
</tr>
<tr>
<td>June 25, 2015</td>
<td>Nuclear power and small modular reactors (SMR) in Indonesia: Potential and challenges</td>
<td>Princeton and Indonesian Institute for Energy Economics Sponsored Workshop, Jakarta, Indonesia</td>
</tr>
<tr>
<td>July 12-16, 2015</td>
<td>Feasibility of detecting plutonium breeding blankets using antineutrinos</td>
<td>56th Annual Institute for Nuclear Materials Management Conference, Indian Wells, USA</td>
</tr>
<tr>
<td>December 7-8, 2015</td>
<td>Detection of breeding blankets using antineutrinos</td>
<td>Applied Antineutrino Physics Meeting, Washington D.C., USA</td>
</tr>
<tr>
<td>December 10-11, 2015</td>
<td>Nuclear verification at low numbers: A scoping workshop</td>
<td>Princeton Hosted Consortium for Verification Technologies Workshop, Princeton, USA</td>
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### Harold A. Feiveson

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<tr>
<th>Date</th>
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<th>Organization/Occasion</th>
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<tbody>
<tr>
<td>October 23, 2015</td>
<td>The Iran Nuclear Deal (with Robert Goldston)</td>
<td>Senior Resource Center, Princeton NJ</td>
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### Robert J. Goldston

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<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
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<tbody>
<tr>
<td>June 3, 2015</td>
<td>The Iran Nuke Deal</td>
<td>The Jewish Center of Princeton</td>
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<tr>
<td>October 23, 2015</td>
<td>The Iran Nuclear Deal (with Harold Feiveson)</td>
<td>Senior Resource Center, Princeton NJ</td>
</tr>
<tr>
<td>November 6, 2015</td>
<td>Technical Aspects of the Iran Nuclear Agreement</td>
<td>Princeton Plasma Physics Laboratory Colloquium</td>
</tr>
<tr>
<td>December 10, 2015</td>
<td>Timeliness at Large Gas Centrifuge Enrichment Plants Presentation (with Mark Walker)</td>
<td>Nuclear Verification at Low Numbers, CVT Scoping Workshop, Princeton University</td>
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<tr>
<td>January 20, 2015</td>
<td>How to Dismantle an Atomic Bomb (Without Spilling the Beans): Information Security in Nuclear Warhead Verification</td>
<td>University of Illinois at Urbana-Champaign</td>
</tr>
<tr>
<td>March 19, 2015</td>
<td>A Zero-knowledge Protocol for Nuclear Warhead Verification</td>
<td>Los Alamos National Laboratory, Los Alamos, New Mexico</td>
</tr>
<tr>
<td>May 10, 2015</td>
<td>How I Learned to Stop Worrying and Dismantle the Bomb: A Research Agenda for Nuclear Verification</td>
<td>IPFM Meeting, Princeton, New Jersey,</td>
</tr>
<tr>
<td>June 15, 2015</td>
<td>Approaches to Nuclear Warhead Counting</td>
<td>PVTS-SGS Workshop on Verification Technologies, Beijing, China</td>
</tr>
<tr>
<td>June 16, 2015</td>
<td>Nuclear Archaeology: Verifying Declarations of Past Fissile Material Production</td>
<td>PVTS-SGS Workshop on Verification Technologies, Beijing, China</td>
</tr>
<tr>
<td>July 13, 2015</td>
<td>Detecting Clandestine Plutonium Separation Activities with Krypton-85</td>
<td>56th Annual INMM Meeting, Indian Wells, California</td>
</tr>
<tr>
<td>July 15, 2015</td>
<td>Virtual Gamma-ray Spectrometry for Template-Matching Nuclear Warhead Verification, 56th Annual INMM Meeting</td>
<td>Indian Wells, California</td>
</tr>
<tr>
<td>July 15, 2015</td>
<td>Two-Color Neutron Detection for Zero-Knowledge Nuclear Warhead Verification</td>
<td>56th Annual INMM Meeting, Indian Wells, California</td>
</tr>
<tr>
<td>September 17, 2015</td>
<td>New Approaches to Trusted Radiation Measurements for Nuclear Warhead Verification, Departmental Seminar</td>
<td>Department of Nuclear Engineering, North Carolina State University, Raleigh, North Carolina</td>
</tr>
<tr>
<td>October 2, 2015</td>
<td>How to Keep a Secret: New Approaches to Trusted Radiation Measurements for Nuclear Warhead Verification, Departmental Seminar</td>
<td>Department of Mechanical and Aerospace Engineering, Princeton University</td>
</tr>
<tr>
<td>October 15, 2015</td>
<td>A. Glaser, Treaty Verification: Characterizing Gaps and Emerging Challenges, CVT Annual Meeting</td>
<td>University of Michigan, Ann Arbor</td>
</tr>
<tr>
<td>November 4, 2015</td>
<td>Minimally Intrusive Approaches to Nuclear Warhead Verification</td>
<td>Sandia National Laboratories, Albuquerque, NM</td>
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Laura Kahn

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<tr>
<td>March 3, 2015</td>
<td>Who’s in Charge? Leadership and One Health</td>
<td>Guest lecturer in One Health class. Texas Tech University. Lubbock, Texas.</td>
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<tr>
<td>March 4, 2015</td>
<td>Physicians, Farmers, and the Politics of Antibiotic Resistance: A One Health Analysis</td>
<td>One Health Seminar. Texas A &amp; M University. College Station, Texas</td>
</tr>
<tr>
<td>April 24, 2015</td>
<td>A Global Health Workforce Through a One Health Framework: A Public Health Perspective</td>
<td>Institute of Medicine workshop Envisioning the Future of Health Professional Education. Washington DC</td>
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<tr>
<td>April 17, 2015</td>
<td>The One Health Initiative</td>
<td>Talk Radio Europe with Pippa Jones</td>
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<tr>
<td>May 1, 2015</td>
<td>Physicians, Farmers, and the Politics of Antibiotic Resistance: A One Health Analysis</td>
<td>School of Veterinary Medicine, Cornell University. Ithaca, NY.</td>
</tr>
<tr>
<td>July 12, 2015</td>
<td>Antibiotic Resistance in the Environment: A One Health Perspective</td>
<td>American Veterinary Medical Association (AVMA) Annual Convention, Boston, MA.</td>
</tr>
<tr>
<td>July 12, 2015</td>
<td>Physicians, Farmers, and the Politics of Antimicrobial Resistance: A One Health Analysis</td>
<td>American Veterinary Medical Association (AVMA) Annual Convention, Boston, MA.</td>
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Zia Mian

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<th>Organization / Occasion</th>
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<tr>
<td>February 11, 2015</td>
<td>What We are Up Against: The Nuclear Future</td>
<td>All Souls Church, New York</td>
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<tr>
<td>February 18, 2015</td>
<td>War and Peace in the Asian Theatre: Pakistan, India, China and the United States</td>
<td>Princeton Old Guard, Princeton University</td>
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<tr>
<td>March 29, 2015</td>
<td>Unmaking the Bomb</td>
<td>Coalition for Peace Action, Princeton</td>
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<td>Organization/Occasion</td>
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<tr>
<td>April 8, 2015</td>
<td>Nuclear Weapons and Power</td>
<td>Program on International Relations and Strategic Affairs, Center for International Security Studies, Princeton University</td>
</tr>
<tr>
<td>April 24, 2015</td>
<td>Connecting the Struggles for a Nuclear-Free, Peaceful, Just and Sustainable World</td>
<td>Peace and Planet Conference, The Cooper Union, New York</td>
</tr>
<tr>
<td>May 1, 2015</td>
<td>The Possible Measures to be Included in a Zone Free of Nuclear Weapons and Other Weapons of Mass Destruction in the Middle East</td>
<td>United Nations Institute for Disarmament Research side event at 2015 nuclear Non-Proliferation Treaty Review Conference, United Nations, New York</td>
</tr>
<tr>
<td>May 6, 2015</td>
<td>After the Nuclear Deal with Iran: Next Steps towards a Middle East Nuclear Weapon Free Zone</td>
<td>IPFM side event at 2015 nuclear Non-Proliferation Treaty Review Conference, United Nations, New York</td>
</tr>
<tr>
<td>June 15, 2015</td>
<td>Overview of Arms Control and Disarmament Verification Challenges</td>
<td>PVTS-SGS workshop on Verification Technologies, Beijing</td>
</tr>
<tr>
<td>September 3, 2015</td>
<td>Understanding the Iran Deal</td>
<td>American Friends Service Committee, Germantown Friends Meeting, Philadelphia</td>
</tr>
<tr>
<td>September 16, 2015</td>
<td>When Diplomacy Succeeds: The Iran Agreement</td>
<td>Princeton Middle East Society, Princeton</td>
</tr>
<tr>
<td>October 2, 2015</td>
<td>The Post-Cold War</td>
<td>Conference on Nuclear Legacies: A Global Look at the 70th Anniversary of the Hiroshima Bombing, Princeton University</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 26, 2015</td>
<td>Walking the Iran Tightrope</td>
<td>Mid-Coast Forum on Foreign Relations</td>
</tr>
<tr>
<td>February 4, 2015</td>
<td>And Then What? Imagining the Middle East if Nuclear Negotiations with Iran Fail</td>
<td>Harvard University</td>
</tr>
<tr>
<td>February 11, 2015</td>
<td>Golden opportunity to seal a diplomatic deal with Iran</td>
<td>Princeton University</td>
</tr>
<tr>
<td>February 16, 2015</td>
<td>Balancing Counter-Terrorism and Human Rights: Challenges and Opportunities</td>
<td>Global Network for Rights and Development (GNRD)</td>
</tr>
<tr>
<td>February 20, 2015</td>
<td>US-Iran Relations</td>
<td>World Affairs Council of Hilton Head</td>
</tr>
<tr>
<td>April 2, 2015</td>
<td>P5+1 &amp; Iran: Report on the Ongoing Nuclear Talks</td>
<td>Carnegie Council for Ethics in International Affairs</td>
</tr>
<tr>
<td>April 8, 2015</td>
<td>Iran Nuclear Framework Agreement</td>
<td>National Council on U.S.-Arab Relations</td>
</tr>
<tr>
<td>April 18, 2015</td>
<td>Relations between Iran and the West after the Lausanne agreement</td>
<td>15th Session of the Korber Dialogue Middle East</td>
</tr>
<tr>
<td>April 20, 2015</td>
<td>Discussion with current and former Iranian nuclear negotiators on Lausanne political framework</td>
<td>Allameh Tabataba’i University</td>
</tr>
<tr>
<td>June 18, 2015</td>
<td>Iran &amp; the US: The Way Forward</td>
<td>The US Army War College</td>
</tr>
<tr>
<td>August 21, 2015</td>
<td>Nuclear deal and Iran’s future as regional power</td>
<td>The Chautauqua Institute</td>
</tr>
<tr>
<td>September 8, 2015</td>
<td>Iran &amp; the US – Beyond the Nuclear Deal</td>
<td>Rotary Club of Oklahoma</td>
</tr>
<tr>
<td>September 12, 2015</td>
<td>Iran &amp; the US: The Nuclear Deal and Beyond</td>
<td>Lancaster Interchurch Peace Witness</td>
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### Abdul Hameed Nayyar

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 2, 2015</td>
<td>What should be the contents of the Environmental Impact Assessment of a nuclear power plant</td>
<td>Workshop organized by the Pakistan Institute of Labour Education and Research and Pakistan Fisher Folk Forum on Karachi’s proposed nuclear power plants</td>
</tr>
<tr>
<td>April 22, 2015</td>
<td>An analysis of the EIA submitted for K2-K3</td>
<td>Second workshop organized by the Pakistan Institute of Labour Education and Research and Pakistan Fisher Folk Forum on Karachi’s proposed nuclear power plants</td>
</tr>
<tr>
<td>October 9, 2015</td>
<td>The Nuclear Karachi; Issues in focus on the K2-K3 project</td>
<td>A workshop organized for journalists by the Pakistan Institute of Labour Education and Research and Pakistan Fisher Folk Forum on Karachi’s proposed nuclear power plants</td>
</tr>
<tr>
<td>November 15, 2015</td>
<td>Pakistan’s quest for nuclear energy</td>
<td>A talk given at the Ghulam Ishaq Khan Institute of Science and Technology, Topi</td>
</tr>
<tr>
<td>December 12, 2015</td>
<td>Issues of concern for K2-K3 power plants</td>
<td>Presentation at a debate on Karachi Nuclear Power Plants held at Habib University, Karachi</td>
</tr>
</tbody>
</table>
### Pavel Podvig

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization / Occasion</th>
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<tbody>
<tr>
<td>May 9, 2015</td>
<td>Use of HEU in Russia</td>
<td>Annual meeting of the International Panel on Fissile Materials, Princeton University</td>
</tr>
<tr>
<td>May 21, 2015</td>
<td>Russian HEU facilities</td>
<td>NAS Committee on the Current Status of and Progress toward Eliminating Highly Enriched Uranium Use in Fuel for Civilian Research and Test Reactors, Washington, DC</td>
</tr>
<tr>
<td>November 11, 2015</td>
<td>The use of highly enriched uranium in Russia. Current status and prospects for minimization</td>
<td>Program on Science and Global Security, Princeton University</td>
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### M. V. Ramana

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organization/Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 23, 2015</td>
<td>Nuclear Energy After Fukushima</td>
<td>Colloquium, Department of Physics, Ohio State University</td>
</tr>
<tr>
<td>March 4, 2015</td>
<td>Atomic Development and Democratic Dissent: Opposition to the Koodankulam Nuclear Plant in India</td>
<td>Lecture, Program for South Asian Studies, Princeton University, Princeton</td>
</tr>
<tr>
<td>April 9, 2015</td>
<td>Nuclear Energy: Global Overview &amp; the Case of India</td>
<td>Program on International Relations and Strategic Affairs, Princeton University &amp; Center for Policy Research, Princeton</td>
</tr>
<tr>
<td>April 16-17, 2015</td>
<td>Accident Risks for High Temperature Reactors</td>
<td>1st International Conference on Nuclear Risks, Vienna</td>
</tr>
<tr>
<td>May 7, 2015</td>
<td>Reprocessing and Breeder Reactors in India</td>
<td>International Panel on Fissile Materials Panel on the Global Challenge of Reprocessing and Plutonium Disposal, NPT Review Conference, United Nations, New York,</td>
</tr>
<tr>
<td>May 22, 2015</td>
<td>The Challenges of Nuclear Safety</td>
<td>International Workshop on Emerging Energy Scenarios in the Middle East, Munib and Angela Masri Institute of Energy and Natural Resources, American University, Beirut</td>
</tr>
<tr>
<td>June 25, 2015</td>
<td>Small Modular Reactors in the United States</td>
<td>Workshop on Nuclear Power And Small Modular Reactors In Indonesia: Potential And Challenges, Indonesian Institute of Energy Economics, Jakarta</td>
</tr>
<tr>
<td>June 26, 2015</td>
<td>Challenges in Licensing Small Modular Reactors</td>
<td>Bapeten (Nuclear Energy Regulatory Agency of Indonesia), Jakarta</td>
</tr>
<tr>
<td>October 5, 2015</td>
<td>Nuclear India: Politics, Rhetoric and Reality</td>
<td>The Alliance for a Secular and Democratic South Asia &amp; Science for the People, Massachusetts Institute of Technology, Cambridge</td>
</tr>
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</table>
### Michael Schoepnner

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<thead>
<tr>
<th>Date</th>
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</tr>
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<tbody>
<tr>
<td>May 9-10, 2015</td>
<td>Atmospheric krypton-85 as an indicator for plutonium separation activities</td>
<td>Annual IPFM meeting 2015, Princeton, USA</td>
</tr>
<tr>
<td>May 12-14, 2015</td>
<td>Impact of radioxenon emissions from IPFs on the global coverage of the IMS noble gas component</td>
<td>WOSMIP, Brussels, Belgium</td>
</tr>
<tr>
<td>June 15-16, 2015</td>
<td>Detecting clandestine plutonium separation activities with krypton-85</td>
<td>CAEP Workshop, Beijing, China</td>
</tr>
<tr>
<td>June 22-26, 2015</td>
<td>Optimization of the network coverage of the IMS noble gas component</td>
<td>CTBT Science &amp; Technology, Vienna, Austria</td>
</tr>
<tr>
<td>July 11-17, 2015</td>
<td>Monitoring Plutonium Separation Activities with Krypton-85</td>
<td>UCS summer symposium, Nagasaki, Japan</td>
</tr>
<tr>
<td>October 15-16, 2015</td>
<td>Optimizing the network coverage of the IMS radioxenon component</td>
<td>CVT Annual Meeting, Ann Arbor, USA</td>
</tr>
<tr>
<td>December 10-11, 2015</td>
<td>Detecting undeclared reprocessing plants</td>
<td>CVT Workshop, Princeton, USA</td>
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### Frank von Hippel

<table>
<thead>
<tr>
<th>Date</th>
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<th>Organization/Occasion</th>
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</thead>
<tbody>
<tr>
<td>March 18, 2015</td>
<td>Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation</td>
<td>Annual meeting of the German Physical Society, Max von Laue Lecture</td>
</tr>
<tr>
<td>March 29, 2015</td>
<td>Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation</td>
<td>Coalition for Peace Action, Princeton, NJ (with Zia Mian)</td>
</tr>
<tr>
<td>April 2, 2015</td>
<td>Plutonium politics in East Asia and in the U.S.</td>
<td>Nuclear Threat Initiative, Washington, DC</td>
</tr>
<tr>
<td>April 10, 2015</td>
<td>From escalation to de-escalation with Iran</td>
<td>Senate staff briefing</td>
</tr>
<tr>
<td>April 10, 2015</td>
<td>Plutonium disposal: Alternatives to MOX</td>
<td>Congressional staff briefing (with Edwin Lyman)</td>
</tr>
<tr>
<td>April 16, 2015</td>
<td>From Escalation to De-escalation</td>
<td>Bulletin of the Atomic Scientists briefing (with Olli Heinonen and Sharon Squassoni)</td>
</tr>
<tr>
<td>May 6, 2015</td>
<td>After the Nuclear Deal with Iran: Next Steps towards a Middle East Nuclear Weapon Free Zone</td>
<td>Nonproliferation Treaty Review Conference, UN (IPFM panel with Zia Mian and Hossein Seyed Mousavian)</td>
</tr>
<tr>
<td>Date</td>
<td>Topic</td>
<td>Event</td>
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<tr>
<td>May 7, 2015</td>
<td>The Global Challenges of Plutonium Separation and Disposal</td>
<td>Nonproliferation Treaty Review Conference, UN (IPFM panel with M.V. Ramana, Mycle Schneider and Tatsujiro Suzuki)</td>
</tr>
<tr>
<td>May 9, 2015</td>
<td>IPFM Report on Alternatives to MOX</td>
<td>International Panel on Fissile Materials annual meeting, Princeton</td>
</tr>
<tr>
<td>May 9, 2015</td>
<td>Converting naval propulsion reactors from HEU to LEU</td>
<td>International Panel on Fissile Materials annual meeting, Princeton</td>
</tr>
<tr>
<td>May 12, 2015</td>
<td>Moving openness about nuclear material stocks into the 21st century</td>
<td>Keynote, Annual Meeting of the U.S. Nuclear Material Management and Safeguards System Community, Las Vegas, Nevada</td>
</tr>
<tr>
<td>May 18, 2015</td>
<td>Plutonium politics in East Asia and in the U.S.</td>
<td>Nonproliferation Education Center, Capitol Hill Club, Washington, DC</td>
</tr>
<tr>
<td>May 18, 2015</td>
<td>Alternatives to MOX: Direct-disposal options for stockpiles of separated plutonium</td>
<td>Congressional staff briefing</td>
</tr>
<tr>
<td>May 19, 2015</td>
<td>Consequences of a spent-fuel pool accident</td>
<td>Science and Global Security Seminar, Princeton University</td>
</tr>
<tr>
<td>June 15, 2015</td>
<td>Contributions of scientists working on verification</td>
<td>Princeton-CAEP Workshop on verification, Beijing, China</td>
</tr>
<tr>
<td>June 18, 2015</td>
<td>Two problems: 1) Accumulation of weapon-useable plutonium, 2) Spent fuel pool safety: One solution: Dry cask storage</td>
<td>Presentation to the Energy Research Committee of Japan’s Diet, Tokyo</td>
</tr>
<tr>
<td>June 18, 2015</td>
<td>Separated plutonium was and still is ‘a clear and present danger.’ Disposing of it in MOX fuel has not worked. What are the alternatives?</td>
<td>Foreign Correspondents Club of Japan, Tokyo</td>
</tr>
<tr>
<td>June 20, 2015</td>
<td>Separated plutonium was and still is ‘a clear and present danger.’ Disposing of it in MOX fuel has not worked. What are the alternatives?</td>
<td>Japan Association of Disarmament Studies, and Institute of World Studies, Takushoku University, Tokyo</td>
</tr>
<tr>
<td>June 23, 2015</td>
<td>Japan’s plutonium policy</td>
<td>Presentation to Assistant Secretary of State for International Security and Nonproliferation, Tom Countryman</td>
</tr>
<tr>
<td>August 5, 2015</td>
<td>Iran nuclear agreement update: 1) What does the agreement say?; and 2) What about the opponents’ complaints?</td>
<td>Coalition for Peace Action, Princeton Public Library</td>
</tr>
<tr>
<td>August 19, 2015</td>
<td>Interview on Iran deal with Rob Goldston</td>
<td>Princeton Community TV</td>
</tr>
<tr>
<td>August 26, 2015</td>
<td>Iran’s Nuclear Program: 1) From escalation to de-escalation; and 2) What happens when the limits are lifted?</td>
<td>Panel, Congressional staff briefing arranged by the National Security Network</td>
</tr>
<tr>
<td>September 4, 2015</td>
<td>Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation</td>
<td>American Political Science Association annual meeting, San Francisco (panel)</td>
</tr>
<tr>
<td>September 10, 2015</td>
<td>Iran’s Nuclear Program: I. From escalation to de-escalation; and II. What happens after 15 years is a problem but not just an Iran problem</td>
<td>Elliot School of International Affairs, George Washington University, Washington, DC</td>
</tr>
<tr>
<td>October 14, 2015</td>
<td>Possibilities for South Australia to expand its involvement in the nuclear fuel cycle</td>
<td>Presentation to South Australia Royal Commission on the Nuclear Fuel Cycle (by Skype)</td>
</tr>
<tr>
<td>October 15, 2015</td>
<td>Verifying and building on the Iran Deal</td>
<td>Consortium for Verification Technology, Annual Meeting, University of Michigan, Ann Arbor</td>
</tr>
<tr>
<td>Date</td>
<td>Topic</td>
<td>Event</td>
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<tr>
<td>October 24, 2015</td>
<td>Planning for the day after the JCPOA’s limit on Iran’s enrichment capacity expires in 10 years</td>
<td>Workshop on “The Iran Nuclear Deal: Implementation, Sustainability, and Prospects for Further Russian-US Cooperation.” hosted by the Center for Energy and Security Studies, Moscow</td>
</tr>
<tr>
<td>October 28, 2015</td>
<td>A ban on HEU production for any purpose</td>
<td>Program on Science &amp; Global Security seminar</td>
</tr>
<tr>
<td>November 3, 2015</td>
<td>The dangers of plutonium separation and safety advantages of dry-cask storage</td>
<td>Pugwash Conference, Nagasaki University,</td>
</tr>
<tr>
<td>November 6, 2015</td>
<td>The economics of plutonium recycle vs. spent fuel storage</td>
<td>Panel, Sasakawa Peace Foundation, Tokyo</td>
</tr>
<tr>
<td>November 6, 2015</td>
<td>Plutonium recycle vs. spent-fuel storage</td>
<td>Panel, New Diplomacy Initiative, Tokyo</td>
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</tbody>
</table>
# APPENDIX D

## Program on Science and Global Security Weekly Seminars

January 1, 2015 – December 31, 2015

<table>
<thead>
<tr>
<th>Date</th>
<th>Speaker</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 11, 2015</td>
<td>Seyed Hossein Mousavian</td>
<td>Golden Opportunity to Seal a Diplomatic Deal With Iran</td>
</tr>
<tr>
<td>March 4, 2015</td>
<td>Patrick Huber, Virginia Tech</td>
<td>Antineutrino Reactor Monitoring and Potential Applications to Safeguards</td>
</tr>
<tr>
<td>March 11, 2015</td>
<td>Laura H. Kahn, Princeton University</td>
<td>Physicians, Farmers, and the Politics of Antibiotic Resistance: A One Health Analysis</td>
</tr>
<tr>
<td>April 1, 2015</td>
<td>Anton V. Khlopkov, Center for Energy and Security Studies (CENESS)</td>
<td>Iranian Nuclear Issue and Prospects for Nuclear Power Development in the Middle East: Russia's Interests</td>
</tr>
<tr>
<td>April 29, 2015</td>
<td>Hugh Gusterson, George Washington University</td>
<td>Drones: A Kinder, Gentler Weapon?</td>
</tr>
<tr>
<td>May 20, 2015</td>
<td>Laura Rockwood, Harvard University</td>
<td>IAEA Safeguards: A View from the Inside</td>
</tr>
<tr>
<td>May 27, 2015</td>
<td>Grégoire Mallard, Graduate Institute of International and Development Studies, Geneva, Switzerland</td>
<td>Regime Complexity in Nuclear Nonproliferation: From the Cold War to the Post-September 11 Era.</td>
</tr>
<tr>
<td>September 30, 2015</td>
<td>Bill von Hippel, University of Queensland</td>
<td>Evolutionary Psychology and Global Security</td>
</tr>
<tr>
<td>October 14, 2015</td>
<td>Benoit Pelopidas, University of Bristol and Visiting Fellow, Princeton Institute for International and Regional Studies, Princeton University</td>
<td>The Closest We Ever Came to Nuclear War: New insights on the 1963 Cuban Missile Crisis and the 1995 Black Brant Event</td>
</tr>
<tr>
<td>November 11, 2015</td>
<td>Pavel Podvig, UN Institute for Disarmament Research and the Program on Science and Global Security at Princeton University</td>
<td>The Use of Highly Enriched Uranium in Russia: Current Status and Prospects for Minimization</td>
</tr>
<tr>
<td>November 25, 2015</td>
<td>Maria Rost Rublee, Monash University, Melbourne, Australia</td>
<td>The Psychology of Atomic Resistance</td>
</tr>
<tr>
<td>December 1, 2015</td>
<td>Li Bin, Tsinghua University</td>
<td>Chinese Thinking on Nuclear Weapons</td>
</tr>
<tr>
<td>December 2, 2015</td>
<td>Megumi Sugimoto, Kyushu University</td>
<td>Forecasting and Preparing for Tsunamis: Lessons from Japan's Experience with the 2011 Tohoku Earthquake and the Fukushima Accident</td>
</tr>
</tbody>
</table>
APPENDIX E

Sources of Funding

January 1, 2015 – December 31, 2015

During 2014, SGS research was funded by the John D. and Catherine T. MacArthur Foundation, Carnegie Corporation of New York, New-Land Foundation, Ploughshares Fund, Rockefeller Brothers Fund and the Simons Foundation.

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