# Preventing Nuclear Catastrophe:
# Strengthening DOE Nuclear Nonproliferation Programs

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## Abstract

Department of Energy (DOE) nonproliferation programs are critical to U.S. national security, and have played central roles in initiatives ranging from securing high-risk nuclear weapons and materials around the globe to constraining Iran's nuclear program. But nuclear proliferation and terrorism threats are constantly evolving, requiring new approaches to address them. This paper identifies opportunities for the Trump administration to advance six critical nuclear nonproliferation objectives:

1. Preventing and responding to nuclear and radiological terrorism;
2. Limiting the spread of nuclear weapons and the technologies needed to make them to additional states;
3. Verifying agreements and detecting and monitoring nuclear programs;
4. Maintaining nuclear weapons for nuclear deterrence (including extended deterrence important for nonproliferation) while easing international concerns;
5. Reducing excess stockpiles; and
6. Developing the tools and building the foundations of future nonproliferation and arms reduction successes.

The paper also offers recommendations on cross-cutting issues, including leadership; coordination; staff development; and relations between DOE headquarters, field offices, and laboratories and facilities.

## Introduction

Department of Energy (DOE) nonproliferation programs are critical to U.S. national security, and have played central roles in initiatives ranging from securing high-risk nuclear weapons and materials around the globe to constraining Iran's nuclear program. But nuclear proliferation and terrorism threats are constantly evolving; the nonproliferation programs of the past may have to adapt to meet the challenges of the future.[1] There has not been a comprehensive review of U.S. nonproliferation policy since the early Obama administration – a time when the Joint Comprehensive Plan of Action with Iran had not been agreed, North Korea's nuclear and missile programs were much less advanced, the United States and Russia were still cooperating on nuclear security and negotiating nuclear arms control, Pakistan and India's nuclear buildups were in their early stages, and the spread and advancement of technology was eight years less advanced than it is today. With a new administration and new circumstances, new approaches are called for. The Trump administration has not yet articulated its approach to these efforts, though it has proposed to cut the budgets for some of them.[2]

The most important proliferation and terrorism risks that DOE programs have the opportunity to address arise from:

- Remaining weaknesses in security for nuclear and radiological materials and facilities, and in interdiction and response after material is stolen or an incident occurs;

- Nuclear and missile programs in North Korea and Iran, which DOE intelligence analysis can help to understand and DOE programs can help to address, by constraining technology flows, supporting negotiations, and supporting verification and implementation of agreements;
- Risks of nuclear use, nuclear buildups, and potentially safety and security issues for existing nuclear weapons programs, including in South Asia and in Russia and China, which DOE cooperative programs can partly help to address;
- Doubts about U.S. extended deterrence guarantees, which contribute to pressures for U.S. allies to proliferate, and which both DOE nuclear weapons programs and DOE nonproliferation programs have a role in addressing;
- Illicit technology procurement by potential proliferators, with the risk augmented by the global spread of technology (including the increasing ability to acquire technology digitally); insufficient international efforts to block such technology flows and respond to proliferators' sophisticated approaches to getting past controls; and advancing technologies (such as 3D printing) that may make some pathways to nuclear weapons easier for proliferators to pursue;
- The spread of enrichment and reprocessing technologies, which offer the potential for states to establish latent capabilities to produce nuclear weapons material rapidly;
- Potential weaknesses in the U.S. and international ability to monitor nuclear programs and verify agreements; and
- Increasingly acute political disagreements among the parties to the nonproliferation regime, with ongoing modernization by the nuclear powers and limited progress in arms reductions putting efforts to strengthen the nonproliferation regime at risk.

Approaches to addressing these challenges should be based on an assessment of where the biggest nuclear proliferation and nuclear terrorism risks lie, and where the biggest opportunities for DOE's particular expertise and resources to contribute to reducing them may be. Even a long-standing effort may not be worth pursuing further if it does little to reduce risk; similarly, even programs targeted on huge risks (such as North Korea's nuclear weapons program) need to be examined for whether they really offer significant potential for reducing the risk. Such assessments should take an integrated approach, looking at capabilities across the U.S. government (and capabilities of partner nations), not just DOE's capabilities.

DOE and its National Nuclear Security Administration (NNSA) should focus their programs for addressing the challenges just identified on six key goals:

1. Preventing and responding to nuclear and radiological terrorism;
2. Limiting the spread of nuclear weapons and the technologies needed to make them to additional states;
3. Verifying agreements and detecting and monitoring nuclear programs;
4. Maintaining nuclear weapons for nuclear deterrence (including extended deterrence important for nonproliferation) while easing international concerns;
5. Reducing excess stockpiles; and
6. Developing the tools and building the foundations for future arms reduction and nonproliferation successes.

The remainder of this paper briefly outlines proposes priorities and approaches in each of these areas. For each category, we also offer a preliminary budget recommendation. Overall, the

approach to risk reduction we suggest would likely require an increase in the range of $140-$160 million compared to FY 2017 funding for DOE nonproliferation programs. The paper concludes with thoughts on approaches to cross-cutting issues such as leadership, staffing, and the relationship between DOE headquarters and the national laboratories.

## 1. Preventing and responding to nuclear and radiological terrorism

Over the past two decades, the United States has made significant contributions to strengthening nuclear security around the globe. DOE has led that effort, helping to remove nuclear weapons-useable material from dozens of countries and providing equipment, training, and technical support that has substantially improved security for HEU, separated plutonium, and radiological sources in many more.

With the end of the nuclear security summit process, the cutoff (at least for now) of nearly all nuclear security cooperation with Russia, and the completion of a number of other initiatives, there is a real danger that nuclear security initiatives will lose momentum, reducing their ability to address the world's remaining nuclear and radiological security challenges. Like nuclear safety, nuclear security requires a focus on continuous improvement, which may not be forthcoming in the absence of energetic U.S. leadership; indeed, without robust U.S. nuclear security programs, nuclear security in a number of countries may begin to degrade, leading to new dangers.

But the era of the United States paying for large-scale equipment installation and training is largely over. Instead, future nuclear security programs should focus primarily on convincing countries to do more themselves – and advising them on how best to do it. As one NNSA official put it to us, the U.S. nuclear security role now is to be "an evangelist and a consultant." Of course, such approaches are not new; the United States has been working to convince other countries to do more on nuclear security, and making suggestions about how to do it, for decades. But the balance is now shifting to these roles as the primary focus.

This transition should be partnership-based, with ideas and resources from each country participating, rather than a donor-recipient model. (Where a country needs U.S. funding for nuclear security measures that would significantly reduce risk, however, the United States should still be willing to provide it.) Listening to other countries' experts, and adapting approaches to the local needs in each location, should be key elements of the approach.

To date, NNSA's nuclear security programs have mainly focused on developing or former Communist countries, though of course there have been some cooperative efforts elsewhere as well. But the evangelist and consultant role is equally applicable for wealthy and "other than high income" countries. The United States should prioritize engagement with countries based on how much risk reduction can be achieved rather than focusing primarily on countries whose resources are limited.

The new approach should draw on the best of past experience. For example, the United States has long held quiet discussions of nuclear security approaches and best practices with countries such as France and Britain – in some cases contributing to substantial improvements. The nuclear security Centers of Excellence that several countries are establishing have provided a focus for providing best practices and understanding of modern equipment and approaches, and a forum for expert discussions. Over time, with groups of local experts focused on nuclear security, they may become champions for improving nuclear security in their own countries and regions.

Effective nuclear and radiological security programs include many elements. But we believe that a focus on genuinely effective implementation in five key areas could lead to substantial improvements in nuclear security over time.[3] Four of the five are already included in International Atomic Energy Agency (IAEA) recommendations – and are therefore part of the Strengthening

Nuclear Security Implementation Initiative (INFCIRC/869) from the 2014 nuclear security summit, which commits states to meet the "intent" of the IAEA's recommendations for nuclear and radiological security.[4] The fifth – consolidating nuclear weapons and weapons-usable nuclear materials to the minimum possible number of sites – is included in a separate summit commitment from 2014, and in a "gift basket" focused on focused on consolidating HEU and minimizing its use.[5] Pushing for genuinely effective implementation around the world in these five areas could serve as the basis for expanded and revitalized DOE nuclear and radiological security programs.

*1. Protecting against the full spectrum of plausible adversary capabilities and tactics.* NNSA should work with states to convince them to protect their dangerous nuclear and radiological materials and facilities against all the capabilities and tactics adversaries might plausibly bring to bear in their country. This set of capabilities and tactics should either be included in the design basis threat (DBT) that operators are required to protect against, or the state should ensure that it provides whatever protection is required beyond the DBT. In an age of terrorists with global reach, nuclear weapons, weapons-usable nuclear materials, and nuclear facilities whose sabotage could cause a major catastrophe should be protected, at a minimum, against a well-placed insider; a modest group of well-trained and well-equipped outsiders, capable of operating as more than one team; and both an insider and the outsiders working together.[6] Facilities or transports in countries facing more substantial adversary threats should have more extensive protection. Protection against cyber threats is another essential element of protecting against the full spectrum of plausible threats. In part by providing information on adversary capabilities and tactics in real incidents – both nuclear and non-nuclear – NNSA can help convince experts in other countries that these threats are plausible and provide support for strengthening DBTs. This is also likely to require efforts to find ways to share sensitive information related to DBTs, while keeping the information confidential; U.S. and Japanese experts, for example, have concluded that a new legal agreement would be needed for them to share DBT information.[7]

*2. Comprehensive programs to protect against insider threats.* Nearly all of the nuclear theft and sabotage incidents where the circumstances are known were perpetrated by insiders within nuclear organizations, or with the help of insiders. Because insiders often know the security system and its weaknesses, protecting against them requires a comprehensive, multilayered approach. DOE should encourage all countries with weapons-usable nuclear materials or major nuclear facilities to adopt such comprehensive insider protection programs. As a consultant, DOE can help develop systems that, among other things, require background checks and ongoing monitoring of behavior; incentivize staff to report concerning behavior or potential vulnerabilities; minimize insider access to weapons-usable nuclear material and vital areas; monitor such material and areas at all times; train staff on protecting against insider threats; develop accurate and timely nuclear material accounting systems; and conduct regular self-assessments.[8]

*3. Programs to strengthen security culture.* Building strong security cultures, in which everyone is keeping an eye out for anything that could suggest a threat or a vulnerability that should be addressed, is fundamental to effective and sustainable nuclear security. But it is very difficult to do in an environment in which major nuclear security incidents rarely occur and resource pressures are ever-present. Every organization handling nuclear weapons or weapons-usable nuclear material, or managing a major nuclear facility should have a focused program in place to (a) assess their security culture, and (b) strengthen it over time. The goal must be a strong focus on continuous improvement in security throughout the organization, with the resources to back it up. DOE has already helped launch security culture programs in a number of countries – but the goal of a focused program for each relevant nuclear organization goes well beyond what has been done so far.

*4. Realistic vulnerability assessment and performance tests.* Security systems can look quite impressive without actually providing much protection against intelligent adversaries looking for ways to defeat them. Hence, achieving genuinely effective security performance requires ongoing vulnerability assessment, with creative teams with a "hacker" mentality assigned to look for weaknesses and propose fixes, and realistic performance testing – including "force on force" exercises in which teams pretending to be adversaries attempt to defeat the security system.

*5. Consolidating weapons-useable nuclear material to fewer locations*. States can achieve stronger security at lower cost by protecting fewer places. Over the past two decades, DOE has helped dozens of countries consolidate weapons-usable nuclear material, or even eliminate such material from their soil.[9] It should continue to play this role, pledging to take back, arrange for the elimination of, or assist in providing effective and sustainable security for all plutonium and HEU anywhere in the world. In the United States, the cost of meeting post-9/11 security requirements provoked substantial consolidation, as managers looked for ways to do without HEU or plutonium, to save costs; DOE should work with countries around the world to ensure that their regulations are structured to provide effective security for HEU and separated plutonium and create similar consolidation incentives. It should also launch a program to assist countries in shutting facilities whose continued benefits no longer outweigh their costs and risks, as a complement to efforts to convert research reactors to use low-enriched uranium.

*Protecting reactors as well as materials.* Beyond the five areas of focus above, there is the question of what DOE should be working to protect. DOE has long worked to improve security for nuclear weapons, weapons-usable nuclear materials, and dangerous radiological materials that could be stolen abroad but used in the United States. DOE should extend this work to include working with countries to strengthen protection against sabotage at nuclear reactors and other nuclear facilities. The disaster at Fukushima made clear that such events abroad can also threaten U.S. interests – and working with countries on sabotage (which they regard as a major concern) can help open the door for cooperation on security for nuclear and radiological materials.

*Leading by example.* To credibly convince other countries to do more, the United States will need to practice what it preaches. As two examples, security for dangerous radiological sources in the United States remains dangerously weak – and few U.S. nuclear organizations yet have targeted programs in place to strengthen their security culture.[10]

*Interdicting nuclear smuggling.* Nearly all of the successful interceptions of stolen plutonium or HEU have been the result of focused police and intelligence work – and luck – rather than radiation detectors. Hence, the first focus of anti-nuclear smuggling effort should be to ensure that key potential transit countries have national units trained and equipped to deal with nuclear smuggling and focused on that effort. Nevertheless, deployment of radiation detection does have some value, particularly to the extent it can channel smugglers to divert toward routes where they are more likely to be caught.

*Budget*. Implementing the nuclear security programs above would be cheap compared to the security stakes, but would require arresting the trend of declining budgets for NNSA nuclear security programs. Congress should reject the Trump administration's proposal to cut NNSA's International Nuclear Security program by 30% compared to fiscal year (FY) 2017, and to cut the Nuclear Material Removal program in half. Overall, Congress should return NNSA nuclear security spending to roughly its FY 2016 level of just over $500 million, roughly an $80-$90 million increase compared to current FY 2017 funding, or $150-$160 million compared to the FY 2018 request.[11]

## 2. Limiting the spread of sensitive nuclear technologies

Every state seeking nuclear weapons in recent years has supported this effort using illicit procurement networks to obtain sensitive technology abroad. And in some cases, most recently Iran, states have built (or considered building) enrichment and reprocessing facilities that were ostensibly peaceful but would offer them a rapid ability to produce weapons material if desired (or to build a secret facility using the same technology). DOE has played a critical role in limiting the spread of sensitive nuclear and dual-use technologies, helping to strengthen export control implementation in the United States and around the world, and working to structure fuel cycle arrangements that reduced countries' incentives to build enrichment and reprocessing facilities of their own. DOE programs should focus on several key areas.[12]

*Expanding efforts to help other countries achieve genuinely effective implementation of strategic trade controls.* DOE should expand its cooperative efforts (including with additional funding), from helping companies handling sensitive technologies to strengthen their corporate compliance programs to training customs officials to help catch illicit dual-use shipments. The United States should work to ensure that the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction makes such trade control assistance even more of a priority. To improve recipient-state commitment and sustainability, to the extent possible, help with proliferation-related controls should be integrated with steps that would strengthen control over contraband developing states often care about more, such as drugs, people, guns, and cigarettes.

*Discouraging nationally controlled enrichment and reprocessing*. This should include assisting other countries in overcoming obstacles to dry cask storage of spent fuel, supporting efforts to structure cooperative international frameworks for managing the fuel cycle (including, ultimately, regional or international spent fuel repositories), building in-country stockpiles of fabricated fresh fuel (to hedge against supply interruptions and thereby reduce the excuse to build national enrichment facilities), and exploring options for putting existing national facilities under multinational control. The U.S. government should consistently seek to encourage states that do not already have enrichment and reprocessing not to build such facilities. Insisting on "gold standard" nuclear cooperation agreements in which states sign away their right to build such facilities, however, is not likely to be a productive approach in most cases.[13]

*Undertaking scenario-based foresight analyses of the impacts of advancing technologies.* New technologies, from 3D printing to new techniques for enriching uranium, are likely to pose new challenges for control – as will the ever-evolving evasion techniques used by proliferation networks and the ongoing spread of potentially sensitive technologies to more countries and more firms. Analyses based on particular scenarios that might unfold 10 to 20 years from now can help controls keep up with the changing technological world.

*Establishing a focused US-China working group on implementation of proliferation controls.* Most of the sensitive technology that Iran and North Korea have acquired for their nuclear or missile programs in the past 15 years has come either from China or through China (purchased elsewhere for ostensibly Chinese and civilian end-users, but then rerouted to its real destinations). Hence, better on-the-ground implementation of strategic trade controls in China's rapidly changing economy is a key element of stemming the spread of sensitive technology – and of implementation of the procurement channel central to the Iran nuclear deal and of sanctions against North Korea. While there is already substantial U.S.-Chinese cooperation in these areas, an in-depth, interagency U.S.-Chinese working group is needed to strengthen Chinese capability and commitment to stopping such illicit trade.

*Building an international nuclear industry advisory panel on strategic trade control.* Companies, as the recipients of procurement requests, are at the front lines in countering proliferation procurement networks. An industry group could provide advice and support for government and international organizations on what is working in strategic trade control, what is not working, and how illicit procurement strategies are evolving. The group could also play a key role in building industry commitment and exchanging best practices in corporate implementation of strategic trade controls. The Botticelli Project appears to be a major step in this direction.[14]

*Budget:* The budget for DOE export control programs was relatively stable throughout the Obama administration, at just above $30 million (including both domestic export control implementation and foreign export control cooperation), and the Trump administration FY18 request is similar. A 2015 advisory report recommended increased funding and additional federal personnel, to expand the number of countries that could be engaged and increase the focus on tracking black-market procurement networks over time.[15] Implementing the initiatives outlined above might require a budget increase in the range of $10 million.

## 3. Verifying agreements and detecting and monitoring nuclear programs

DOE laboratories play a critical role in developing technologies for detecting, monitoring, verifying, and responding to nuclear proliferation threats. Most recently, DOE played a significant role in ensuring the success of the Joint Comprehensive Plan of Action negotiated with Iran; DOE experts provided both deep insights into Iran's nuclear technologies and ideas about how to verify the nuclear deal. In 2014, the Defense Science Board called for an expanded technology effort focused on both verification of agreements and detecting and monitoring proliferation efforts not covered by agreements, arguing that monitoring "will need to be continuous, adaptive, and continuously tested for its effectiveness against an array of differing, creative and adaptive proliferators."[16] DOE has the largest nuclear verification R&D effort in the U.S. government and must play a central role in such a strengthened effort.

Particularly difficult and critical monitoring and detection challenges include detecting secret weapons material production or weaponization activities (or confirming their absence) and attempting to confirm total stockpiles of weapons-usable nuclear material or nuclear weapons (including through nuclear archaeology at a broad range of types of production facilities). Tools will range from new approaches to detecting and analyzing signatures of current and past production to machine-assisted analysis of vast quantities of all-source text, procurement data, and other information to identify potential indicators of illicit activity. DOE R&D and policy efforts should also continue to work to strengthen IAEA safeguards—both in the ability to detect undeclared activities and to conduct effective verification at declared facilities, particularly enrichment and reprocessing facilities capable of producing weapons-usable nuclear material. A robust research and development program in these areas can help build the tools for future nonproliferation successes.

*Budget:* Including both R&D and implementation programs focused on safeguards and verification, DOE spends $300-$350 million/year on verification and monitoring.[17] Appropriately targeted, the current level of funding could lead to major progress – but there is always more R&D that could be done. An additional roughly $50 million, including funding targeted on areas that have not yet received sufficient attention – such as advanced techniques for nuclear archaeology – would be well-placed.

## 4. Maintaining nuclear deterrence while minimizing international concerns

Though DOE's weapons programs are separate from its nonproliferation programs, maintaining credible extended deterrence is important to continuing to convince threatened U.S. allies not to build nuclear weapons of their own. At the same time, however, the majority of the

parties to the nuclear Nonproliferation Treaty (NPT) believe the United States and other nuclear weapon states are not doing enough to fulfill their treaty obligation to pursue nuclear disarmament; U.S. programs apparently designed to maintain a substantial nuclear arsenal effectively forever inevitably raise international concerns. Hence, DOE needs to walk a fine line, ensuring that the U.S. nuclear arsenal remains safe, secure, and effective without taking provocative actions that could further alienate non-nuclear weapon states and undermine their willingness to support strengthened nonproliferation measures. Toward this end, the U.S. government should (a) avoid design, development, and production of new nuclear weapons; (b) avoid a return to nuclear testing; (c) further reduce the reserve warhead and fissile material stockpiles; (d) increase the level of effort focused on warhead dismantlement and arrange for international visibility for that effort (such as unclassified visits to Pantex); (e) expand efforts to work with other countries to develop credible disarmament verification techniques; and (f) place U.S. excess plutonium and HEU stockpiles under international monitoring.

Moreover, as the cost of DOE's nuclear weapons programs continues to grow, with little prospect for large overall increases in the department's budget, there will be greater pressure to siphon funds from U.S. nonproliferation programs. In determining how to allocate NNSA funds, DOE should compare the relative risk reduction that could be achieved with the next marginal investment in each area, looking for ways to maintain both an effective deterrent and effective nonproliferation programs at minimum cost and risk.

## 5. Reducing excess stockpiles

Reducing stockpiles of nuclear weapons, plutonium, and HEU that are no longer needed is also important to U.S. nonproliferation and arms control objectives. Unfortunately, DOE's programs in this area are either proceeding too slowly (including warhead dismantlements and HEU disposition) or are pursuing unworkable approaches – in particular the plan to use excess plutonium as mixed oxide (MOX) fuel in nuclear reactors. At present, the life-cycle cost for the MOX program is estimated at over $30 billion, with 2048 as the *start* date for fabricating fuel. The national security benefit of the MOX effort is simply not worth the cost. The MOX program should be terminated in favor of the quicker and cheaper "dilute and dispose" option favored by both the Obama and Trump administrations. The U.S. government should seek to convince Russia to agree to amend the plutonium disposition agreement to accommodate this U.S. approach (as it was amended previously to accommodate a changed Russian approach); this might be possible if U.S.-Russian relations improve. For either approach, DOE should ensure the highest practicable standards of security and accounting throughout the process, and plan for international verification (and seek the same in Russia). DOE should seek to work with countries with excess stocks of civilian separated plutonium to work out cheaper and better approaches to reducing those stocks than using them as MOX. The money saved by terminating the MOX effort can support the other expanded nonproliferation efforts discussed above.

## 6. Developing the tools and building the foundations for future nonproliferation and arms reduction successes

To ensure that it has what it needs to meet future challenges, DOE must invest in technologies, facilities, and people. Technology R&D was discussed above – but it should go beyond verification and monitoring technologies, including development, for example, of better technologies for material protection, control, and accounting and emergency response; continued development of more proliferation-resistant nuclear energy systems; and development of low-enriched fuels (or other alternatives) for high-performance research reactors and, ultimately, naval reactors. DOE should set aside a modest portion of its R&D funding for competitively awarded grants for high-risk, high-reward ideas.[18] DOE will need to invest in modernization of a range of

R&D and test facilities to ensure that it maintains the cutting-edge facilities required to remain at the forefront of understanding and responding to nuclear challenges.

But investing in the next generation of people is perhaps most fundamental. More than a third of the NNSA workforce – over 900 people— will be eligible for retirement by 2022 (though many may stay longer).[19] There is an urgent need to recruit, train, and retain the next generation of nonproliferation professionals. Congress and DOE should work together to ensure that DOE has the funding, the federal slots, and the flexibility needed to provide attractive opportunities for young people to join the effort. This could include expanding the NNSA Graduate Fellowship Program (NGFP) to bring in larger numbers of recent graduate students as more retirements are expected.

*Budget:* The budget for these reinvestment efforts must be included in the budgets for each of its key nonproliferation efforts. For the NGFP in particular, the Trump administration has proposed just over $3 million for the nonproliferation portion for FY 2018; even doubling that figure would amount to a very small percentage of the overall nonproliferation budget.

## Cross-cutting issues

For any of these expanded programs and new strategies to be effective, DOE will need strong leadership, a positive, performance-oriented culture, and a renewed partnership between headquarters and its labs and facilities. In each of these areas, there are signs of progress, but there is a great deal still to be done. In 2014, for example, an employee survey ranked NNSA 228th out of 315 similarly sized agencies as a good place to work – while in 2016, NNSA had moved up to 153rd out of 305.[20]

There remains a need for greater collaborative decision-making, where technical experts have a seat at the table and senior leadership within DOE are receptive to new ideas. This includes working in real partnership with the labs – including soliciting their input on ideas, approaches, and priorities. It is critical to make optimal use of the deep expertise that resides in the laboratories, rather than treating them as "just another contractor," used only to answer narrow technical questions.[21] Cutting back on the layers of bureaucracy that impede effective work – including some experts charging their time in 15-minute increments – is likely to be essential.

DOE has the largest nonproliferation programs and the deepest expertise on nuclear weapons and the materials and technology needed to make them that exist in the federal government. Putting together a compelling vision, a plan to accomplish it, with the resources, authorities, people, and facilities needed to get the job done, is critical to meeting the nuclear proliferation and terrorism challenges the world faces.

## REFERENCES

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[2] See U.S. Department of Energy, *FY 2018 Congressional Budget Request: National Nuclear Security Administration*, Vol. 1, (Washington, D.C.: DOE, May 2017), p. 4. All proposed budget numbers for fiscal year 2018 mentioned in this paper come from this document.

[3] For more, see Matthew Bunn, Martin B. Malin, Nickolas Roth, and William H. Tobey, "Key Steps for Continuing Nuclear Security Progress," CN-244-574, International Conference on Nuclear Security: Commitments and Actions, International Atomic Energy Agency, Vienna, Austria, December 5-9, 2016, http://www.belfercenter.org/sites/default/files/files/publication/%5B3A-1%5D_FUL_574_Bunn.pdf.

[4] See International Atomic Energy Agency, "Communication Received From the Netherlands Concerning the Strengthening of Nuclear Security Implementation," INFCIRC/869 (Vienna: IAEA, 2014), https://www.iaea.org/sites/default/files/publications/documents/infcircs/infcirc869.pdf.

[5] The 2014 nuclear security summit communique called for HEU and separated plutonium to be appropriately "secured, *consolidated,* and accounted for" (emphasis added); called for states to "minimize their stocks of HEU and keep their stockpile of separated plutonium to the minimum level"; and encouraged states to continue to "minimize the use of HEU through the conversion of reactor fuel from HEU to LEU." See "The Hague Nuclear Security Summit Communique" (The Hague: Foreign Ministry of the Kingdom of the Netherlands, March 25, 2014), https://tinyurl.com/r35t8f9. A 2016 summit "gift basket" committed participating states to "make every effort" to make progress on "minimizing and eliminating" the use of HEU in civilian applications. See "Gift Basket on Minimizing and Eliminating the Use of Highly Enriched Uranium in Civilian Applications" (Washington, D.C.: U.S. Department of State, April 1, 2016), https://tinyurl.com/yx3ffq8s.

[6] See Matthew Bunn and Evgeni P. Maslin, "All Stocks of Weapons-Usable Nuclear Materials Worldwide Must be Protected Against Global Terrorist Threats," *Journal of Nuclear Materials Management,* Vol. 39, No. 2 (Winter 2011), pp. 21-27.

[7] Interviews with U.S. National Security Council and NNSA officials, February 2016.

[8] See Matthew Bunn and Scott D. Sagan, eds., *Insider Threats*, (Ithaca, NY: Cornell University Press, 2017).

[9] See Matthew Bunn, Martin B. Malin, Nickolas Roth, and William H. Tobey, *Preventing Nuclear Terrorism: Continuous Improvement or Dangerous Decline?* (Cambridge, MA: Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard Kennedy School, 2016), pp. 60-65.

[10] For the radiological issue, see, for example, Government Accountability Office, *Nuclear Nonproliferation: Additional Actions Needed to Increase the Security of U.S. Industrial Radiological Sources,* GAO-14-293 (Washington, D.C.: GAO, June 2014), https://www.gao.gov/assets/670/663917.pdf.

[11] We count International Nuclear Security, Radiological Security, HEU Reactor Conversion, and Nuclear Material Removal as NNSA nuclear security programs.

[12] These recommendations are based primarily on Martin B. Malin, Matthew Bunn, Leonard Spector, William Potter, eds., *Preventing Black-Market Trade in Nuclear-Related Technologies* (Cambridge University Press, forthcoming).

[13] Matthew Bunn and Fred McGoldrick, "A Nuclear Blind Alley for the United States," *Los Angeles Times,* December 3, 2013, http://articles.latimes.com/2013/dec/31/opinion/la-oe-bunn-nuclear-proliferation-20131231.

[14] See, for example, Sandro Zero and Chantho Creze, "Botticelli Project: Enhancing Export Control Cooperation Between Industry and Governments," presented at the 20th Pacific Basin Nuclear Conference (PNBC 2016), April 5-9, 2016, Beijing, https://tinyurl.com/ycwt9ydv.

[15] Secretary of Energy Advisory Board, Report of the Task Force on Nuclear Nonproliferation, p. 21.

[16] Defense Science Board, *Task Force Report on the Assessment of Nuclear Treaty Monitoring and Verification Technologies* (Washington, D.C.: Department of Defense, January 2014) http://www.acq.osd.mil/dsb/reports/2010s/NuclearMonitoringAndVerificationTechnologies.pdf.

[17] This includes the "international nuclear safeguards" and "nuclear verification" parts of NNSA's "nonproliferation and export controls" budget and the "proliferation detection" portion of NNSA's nonproliferation R&D budget, but not the "nuclear explosion detection" portion, which is largely focused on procurement of nuclear explosion detectors for deployment on Air Force satellites, on which NNSA is spending $164 million in FY 2017.

[18] Secretary of Energy Advisory Board, *Report of the Task Force on Nuclear Nonproliferation,* p. 22.

[19] NNSA Office of Civil Rights, "Total NNSA workforce", April 1, 2017, https://nnsa.energy.gov/sites/default/files/nnsa/multiplefiles/nnsa_fy17_0.pdf.

[20] Partnership for Public Service and Deloitte, "The Best Places to Work in the Federal Government: 2014 Rankings (Washington, D.C.: Partnership for Public Service, 2014), http://bestplacestowork.org/BPTW/; "National Nuclear Security Administration, Agency Report, Best Places to Work Rank 2016," http://bestplacestowork.org/BPTW/rankings/detail/DN08.

[21] See U.S. Department of Energy, *Transition 2016: Corporate Overview Appendices* (Washington, DC, 2016) https://www.eenews.net/assets/2017/04/17/document_gw_04.pdf.