Nuclear nonproliferation policy in a sustainable energy future

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The changing state of international affairs related to nuclear technology precipitated updates and revisions to ANS's Position Statement #55.

THE AMERICAN NUCLEAR Society's Special Committee on Nuclear Nonproliferation recently updated Position Statement #55 (PS#55), *Nonproliferation,* to reflect developments since the statement was originally issued in 2001. The committee was formed in 1995 to make specific recommendations to decision makers, the ANS membership, and the general public regarding nuclear nonproliferation issues. The committee, which evolved from a special panel led by Glenn Seaborg, was commissioned by ANS to assess the measures needed to protect and manage plutonium,[1] both from the dismantling of nuclear weapons by the Russian Federation and the United States, and from the operation of nuclear reactors throughout the world.

The original PS#55 emphasized the need for U.S. leadership and collaboration to enhance global nuclear proliferation management.[2] The updates the committee has made to the statement are based on the changing state of international affairs related to nuclear technology, national defense, and energy security and reflect the views, knowledge, experience, and insights of numerous members of the nuclear science professional community in the United States.

PS#55 concerns primarily the proliferation resistance and physical protection of materials in the nuclear fuel cycle, and it also addresses the disposition of excess weapons-grade materials. It does not, however, take a position on nuclear weapons reduction, as that is a national defense matter. Specifically, it does not address the results of the U.S. Nuclear Posture Review announced on April 6, 2010[3] (*NN,* May 2010, p. 45), but it does address important issues that will shape global nonproliferation policy in the coming years. The 2009 revision of PS#55 was evolutionary in nature and preserved the fundamental precepts of the original statement.

The key outcomes of the National Security Summit, hosted by the United States on April 12 and 13 in Washington, D.C.[4] (*NN,* May 2010, p. 17), were agreements by the 47 attending countries to secure all vulnerable nuclear materials within four years and calls for focused national efforts to improve the security and accounting of nuclear materials. PS#55 is fully compatible with the results of the summit, and also more broadly addresses global nuclear nonproliferation policy in a sustainable energy future.

What's behind the statement?

In the 20th century, mankind made amazing strides in nuclear science and technology that have provided enormous benefits. Controlled nuclear fission is a source of reliable, large-scale energy production around the world (currently about 20 percent of electricity generated in the United States, and about 16 percent globally), and radioisotopes are indispensable for various basic research techniques, industrial processes, and medical procedures.[5] In fact, approximately one-third of all patients entering hospitals in the United States will undergo some form of nuclear medical diagnostic or therapeutic procedure.

In contrast, nuclear weapons of enormous destructive power pose a threat to international security. Since the first and only use of nuclear weapons in 1945, the United States and many other countries have striven to limit the spread of such weapons, with the ultimate goal of their elimination.[6] The goal of nuclear nonproliferation, as embodied in the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), has been widely accepted in the international community and continues to be a cornerstone of international security, but the threat of nuclear proliferation has evolved with the changing state of international affairs.[7-8]

An effective nonproliferation policy must deal with the following broad-based threats:

1. Diversion of fissile material from the nuclear fuel cycle.
2. Theft of fissile material by subnational or terrorist groups.
3. Clandestine operation of a fissile material production facility.

The proliferation of nuclear weapons can occur through sovereign states, with a recent notable example being North Korea. Proliferation to subnational groups must also be prevented; this is primarily a concern with respect to the theft of a nuclear weapon or fissionable material from which a weapon can be fashioned. Effec-

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tively dealing with these threats requires the active leadership and involvement of the United States. This will require a flexible U.S. approach to dealing with diverse situations and possible new threats, and with the emergence and application of new technologies.

Historically, nations have utilized only unsafeguarded research reactors, special-purpose reactors, or isotope separation facilities to produce the quantities of high-quality plutonium and high-enriched uranium (HEU) that are needed for nuclear weapons,[6] but other civil-sector materials and technology can also potentially be used to make nuclear weapons.[9] Accordingly, there is widespread agreement that if the world is to realize the many benefits of nuclear power in the future, it is imperative that the peaceful applications of this technology continue in a way that does not contribute to the spread of nuclear weapons and that gives the public confidence that the diversion of civil nuclear materials into weapons programs will not occur. This is one of the prime objectives of the global nonproliferation regime, which the United States has played a key role in promoting.

The six points of the position statement

Both the old and new versions of PS#55 include six points stating ANS's position on nonproliferation. Each of the points, as revised in the 2009 version of the statement, is stated below (in italics), with relevant discussion of recent developments and current conditions following each point.

1. Nuclear science and technology can be applied for peaceful purposes in a manner that fully supports and is compatible with achieving nonproliferation goals, as embodied in the [NPT]. To prevent proliferation, sovereign states should adhere to the NPT and its safeguards system, including the additional protocol, and adopt effective export controls. Incentives to acquire nuclear weapons must also be addressed through foreign policies that discourage clandestine nuclear weapons programs in all nations. ANS endorses the steps to strengthen the NPT contained in United Nations Security Council Resolution [UNSCR] 1887.

The NPT was initially adopted by the United Nations on June 12, 1968. The goals of the NPT, according to the International Atomic Energy Agency, are to prevent the spread of nuclear weapons and weapons technology, to foster the peaceful uses of nuclear energy, and to further the goal of disarmament. The NPT establishes a safeguards system under the purview of the IAEA, which also plays a central role under the treaty in the area of technology transfer for peaceful purposes. And so, not only can nuclear science and technology be applied for peaceful purposes in a manner that fully supports and is compatible with achieving nonproliferation goals, this peaceful application and related technology transfer is endorsed by the NPT.

Over the course of more than 40 years, the NPT has been a successful instrument of international security. At the beginning of the nuclear age, some felt that dozens of countries would acquire nuclear weapons as an instrument of national security. Instead, by and large the nations of the world have accepted the premise that a world with many nuclear weapons states would be more dangerous for weapons states and nonweapons states alike. Libya's renunciation of nuclear weapons in 2003 was a notable example of successful international nonproliferation efforts, as were the decisions by countries arising from the former Soviet Union to transfer their nuclear weapons arsenals to Russia. There have been exceptions, but overall the NPT has done its job and continues to enjoy broad support in the international community.

In May 1997, the IAEA issued the model additional protocol to be adopted by sovereign states. The additional protocol is a legal document that grants the IAEA inspection authority that is complementary to that provided in underlying safeguards agreements, including expanded rights of access to information and sites. A key provision is that a sovereign state that has adopted the additional protocol must provide information about and access to all parts of its nuclear fuel cycle.

Revised PS#55 calls for foreign policies that discourage clandestine nuclear weapons programs. The current situations in North Korea and Iran, both signatories to the NPT, highlight the need for such foreign policies and associated international responses to these countries' violations of the NPT.

UNSCR 1887 was adopted on September 24, 2009, at a historic summit meeting presided over by President Barack Obama and addressed by 13 other heads of state. The Security Council reaffirmed its strong support for the NPT and called on sovereign states to comply fully with their obligations under the NPT and to set realistic goals relative to the disarmament of countries that currently possess nuclear weapons, nonproliferation to countries not yet in possession of nuclear weapons, and the peaceful use of nuclear energy for all. UNSCR 1887 contains detailed endorsements of commitments under the NPT, the additional protocol, and UNSCR 1540 (discussed later under Point 5). If these endorsements are applied effectively, the technical, political, and institutional factors that constitute the key elements of a global nonproliferation regime will provide a continued high level of confidence that civil nuclear facilities and materials will not be diverted to military programs.

It is encouraging that many countries are setting a positive example of how to establish commercial nuclear power within the NPT framework.

According to the IAEA, at the end of 2009 there were 438 nuclear power reactors operating in 30 countries, with a total net installed capacity of 372 GWe.* Approximately 50 countries that do not presently have nuclear power reactors have approached the IAEA for assistance in establishing an appropriate framework for commercial nuclear power. It is encouraging that many countries—for example, the United Arab Emirates, Jordan, Turkey, and Vietnam—are setting a positive example of how to establish commercial nuclear power within the NPT framework.

2. Successfully addressing current and evolving proliferation threats requires that the United States work effectively with both industrialized and developing nations and with established international institutions such as the [IAEA]. U.S. governmental policy and actions should accept the variety of approaches toward nonproliferation chosen by other countries. In particular, European nuclear power programs have demonstrated that effective safeguards can be designed into programs that involve the separation of plutonium in the fuel cycle. ANS strongly endorses[10] an orderly transition to a U.S. policy that encompasses nuclear fuel recycling in parallel with the establishment of a high-level waste repository.

The need for the active involvement of the United States arises from its broad global responsibilities, extensive nuclear weapons stockpile, and status as the world's leading generator of electrici-

*The *NN* World List of Nuclear Power Plants shows 439 operable reactors and a total capacity of roughly 375 GWe (as of December 31, 2009). The variations are a result of differing criteria used to determine the plants to be included in the year-end total (such as connection to the grid [IAEA] vs. commercial operation [*NN*] to determine the start date of operability).

ty from nuclear power. Given the varying energy needs around the world and the diversity of fuel cycle options of today and of the future, the nonproliferation regime cannot practically be tied to one particular fuel cycle. U.S. governmental policy and actions should accept the variety of approaches toward nonproliferation chosen by other countries, including the use of alternative fuel cycles. This may be the most controversial part of PS#55, because for decades the United States has pursued and implemented a policy that actively discourages the recycling of used nuclear fuel, both domestically and abroad.

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Despite U.S. concerns about fuel recycling, European nuclear power programs have demonstrated that effective safeguards can be designed into programs that involve the separation of plutonium in the fuel cycle.[11] Over the past 50 years, the principal reason for reprocessing used nuclear fuel has been to recover unused uranium and plutonium and thereby close the fuel cycle, in the process gaining more energy from the original uranium and thus contributing to energy security. A secondary reason is to reduce the volume of material requiring disposal as high-level waste. In addition, the level of radioactivity in the waste from reprocessing is much lower, and after about 100 years decreases much more rapidly than it does in unreprocessed fuel.[12]

Industrial-scale reprocessing has been carried out at La Hague in France and at Sellafield in the United Kingdom for decades, and significant amounts of the resulting plutonium have been fabricated into mixed-oxide (MOX) fuel for use in commercial nuclear power reactors in Belgium, France, Germany, Japan, and Switzerland. Annual reprocessing capacity is now about 4000 metric tons per year for normal oxide fuels, but not all of that capacity is operational. In addition, Japan is starting up a large-scale reprocessing facility to support its fleet of nuclear power reactors.

All nuclear fuel cycles that involve fissile material are potentially vulnerable to the theft or diversion of that material. Intrinsic attributes alone are not sufficient to prevent the spread of nuclear weapons; extrinsic safeguards measures must be employed effectively and consistently around the world in order to achieve nonproliferation goals.[13]

3. ANS encourages the U.S. government to establish a policy that definitively endorses peaceful applications of nuclear technology. A strong domestic nuclear industry and supporting infrastructure are essential to the credibility of the United States in working effectively with other countries in meeting the proliferation challenges of today and tomorrow. ANS applauds[14] efforts by agencies of the U.S. government to revitalize the nuclear workforce and to support education programs in nuclear science and technology.

Since 2001, and particularly during the past five years, the domestic nuclear infrastructure has strengthened in response to the renaissance of interest in nuclear power. Currently there are four signed engineering, procurement, and construction contracts for eight new nuclear power plants in the United States, and the Nuclear Regulatory Commission has received applications for combined construction and operating licenses for a total of 26 potential new power reactors. Improvements continue to be made in U.S. manufacturing capability and in the infrastructure to provide education and training of nuclear power personnel.

In his milestone speech on minimizing the potential for proliferation given in Prague on April 5, 2009,[8] President Obama endorsed the principle that "all countries can access peaceful nuclear energy," and further stated, "We must harness the power of nuclear energy on behalf of our efforts to combat climate change, and to advance peace and opportunity for all people." Obama gave his most candid endorsement of peaceful nuclear power during a town hall meeting in New Orleans on October 16, 2009: "There's no reason why technologically we can't employ nuclear energy in a safe and effective way. Japan does it and France does it, and it doesn't have greenhouse gas emissions, so it would be stupid for us not to do that in a much more effective way." In his State of the Union Address on January 27, 2010, Obama said, "To create more of these clean energy jobs, we need more production, more efficiency, more incentives. And that means building a new generation of safe, clean nuclear power plants in this country."

These comments have set the stage for a U.S. government policy that definitively endorses peaceful applications of nuclear technology as encouraged by PS#55. The first substantive evidence of that policy came on February 16, 2010, when Obama announced that the Department of Energy had offered conditional commitments for a total of $8.33 billion in loan guarantees for the construction and operation of two new nuclear power reactors at Plant Vogtle in Burke County, Ga.[15] This project is the first U.S. nuclear power plant to break ground in nearly three decades. The president's fiscal year 2011 budget requests an additional $36 billion in loan authority, which would triple the current loan guarantee authority for nuclear energy.[16]

Further evidence of U.S. government policy development is provided by Energy Secretary Steven Chu's January 29 announcement of the appointment of the Blue Ribbon Commission on America's Nuclear Energy Future.[17] The announcement described this action "as part of the Obama administration's commitment to restarting America's nuclear industry," and also stated, "The administration is committed to promoting nuclear power in the United States and developing a safe, long-term solution for the management of used nuclear fuel and nuclear waste."

4. The United States should continue to explore and develop technologies that will further enhance the proliferation resistance of nuclear power systems. The safeguarded civilian nuclear fuel cycle needs to remain an unattractive route for acquiring nuclear weapons. U.S. research and development policy should recognize the widely held view that the long-term benefits of nuclear power will depend on utilizing more fully the vast potential energy resources in uranium[10] and thorium.[18] Consequently, research and development of recycle options is warranted to ensure a secure and sustainable energy future with reduced proliferation risk.[10]

Commercial reprocessing plants use the well-proven aqueous plutonium-uranium extraction (PUREX) process, which involves dissolving used fuel elements in concentrated nitric acid and then chemically separating the uranium and plutonium. The plutonium and uranium can then be recycled as fuel, with the uranium going to the conversion plant prior to reenrichment and the plutonium going straight to MOX fuel fabrication. The primary proliferation concern with the PUREX process is that the separated plutonium can also be used to make weapons of mass destruction (WMD).[12]

A modified version of the PUREX process that does not involve the isolation of a plutonium stream is the uranium extraction (UREX) process, developed by the DOE under the Fuel Cycle Research and Development (FCRD) program (formerly the Advanced Fuel Cycle Initiative). With UREX, only uranium is recovered initially for recycle, and the residual is treated to recover plutonium with other transuranics. The fission products then comprise most of the high-level waste. This system is attractive because it provides some measure of increased intrinsic proliferation resistance by keeping the plutonium with other transuranics, all of which can then be destroyed by recycling in fast reactors. While it would be more difficult for a subnational group to acquire pure plutonium by obtaining material from the UREX process than from the PUREX process, it is important to remember that any fuel cycle process involving plutonium has some level of proliferation concern that must be addressed using extrinsic measures. European facilities have amply demonstrated that PUREX processes can be adequately safeguarded.

Electrometallurgical processing techniques (pyroprocessing) to separate nuclides from a radioactive waste stream have been under development at DOE laboratories (notably Argonne) for many years, as well as in Korea, France, and Japan. Pyroprocessing uses industrial electrorefining techniques to produce three product streams from used nuclear fuel: uranium, actinides (including plutonium), and fission products. The process was developed for metal fuels but can be applied to oxide fuels with the addition of a front end oxide-to-metal reduction step. The potential nonproliferation advantage of pyroprocessing over aqueous separation techniques is that pure plutonium is not separated, and the plutonium and other heavy elements can be fabricated into fast reactor fuel. Further development and demonstration of pyroprocessing should continue under the FCRD program, since it has a potential role in future nonproliferation policy related to the recycling of used nuclear fuel.

Another promising area of development involves small modular reactors (SMR), sometimes called grid-appropriate reactors, which would be tailored to the grid capacity of a particular region or country. SMR concepts offer the potential for longer fuel cycles and a fuel supply-and-return policy between nations that have enrichment and reprocessing capabilities and developing countries. Implementing this fuel supply-and-return policy reduces the opportunity for proliferation. Energy Secretary Chu recently stated, "Our choice is clear: Develop these technologies today or import them tomorrow."[19] This statement should be extended to all phases of nuclear technology as advocated by Point 4 stated above.

5. The United States should continue to invest in the development of technologies to monitor and safeguard nuclear materials. This includes strengthening material accountability and physical protection of nuclear materials in cooperation with other countries and the IAEA. ANS endorses the principles and objectives of [UNSCR] 1540, which requires nation states to implement "effective measures to establish domestic controls to prevent the proliferation of nuclear . . . weapons . . . , including by establishing controls over related materials" and to criminalize export control violations, and calls for states to assist one another to implement such controls.

UNSCR 1540, which was extended by UNSCR 1673 in 2006 and UNSCR 1810[20] in 2008, requires that states take measures to prevent nuclear terrorism, with a particular focus on prohibiting non-state actors from acquiring or using nuclear weapons and on further measures to control nuclear materials and prevent proliferation. The intent of UNSCR 1540 is to address security concerns and to build collaborative relationships between nuclear weapon states and non-nuclear weapon states. The resolution recognizes the importance of making progress on nuclear disarmament and nuclear nonproliferation and provides opportunities for states to take actions to further both. In particular, the resolution provides opportunities for states to prohibit nuclear weapons comprehensively, regardless of who currently possesses or is attempting to possess them, and to adopt criminal laws applying to both state and non-state actors.

Fundamentally, there are two lines of defense to ensure that nuclear weapons and materials stay out of the hands of terrorists. The first line of defense is to secure nuclear weapons and nuclear and radiological materials at their source and includes the physical security, control, and accountability of nuclear weapons and materials. Inspections are periodically performed to identify whether any diversion of nuclear materials from peaceful activities has occurred. These inspections rely on material accountability, physical security, and containment and surveillance.

With respect to research reactors, the first line of defense includes converting from HEU fuel to low-enriched uranium (LEU) fuel, and repatriating HEU fuel to its country of origin. Substantial progress has been made in this area (see discussion that follows Point 6).

The second line of defense consists of developing an infrastructure to deter, detect, and respond to illicit transfers of weapons-usable nuclear and radiological materials, as well as sensitive nuclear weapons technology. The infrastructure includes developing and deploying cutting-edge radiation detection systems at high-risk border crossings, airports, and seaports. For example, by 2015, the DOE's Megaports Initiative[21] seeks to equip 100 seaports with radiation detection systems that will scan approximately 50 percent of global maritime containerized cargo. The DOE has partnered with other countries to install detection systems in 27 ports around the world since 2003, and implementation is under way at another 16 ports. In addition, export control and WMD-awareness training of customs officials strengthens their ability to deter and detect WMD-related technology transfers.

Concern over the theft or diversion of HEU is especially acute because HEU is considered the least difficult material from which to fashion a fission bomb.

6. Significant quantities of weapons-grade plutonium and [HEU] pose a continuing proliferation threat to the world community. Important efforts to secure these materials and to transform them into more proliferation-resistant forms require and warrant substantial attention and resources. Significant progress has been made with HEU. Essential programs such as plutonium disposition[22] will require sustained and stable support from the United States and other countries over many years.

Concern over the theft or diversion of HEU is especially acute because HEU is considered the least difficult material from which to fashion a fission bomb. The Megatons to Megawatts program,[23] which began in 1994, involves the downblending of Russian HEU for use as fuel in U.S. nuclear power plants. By 2009, more than 382 metric tons (t) of Russian HEU had been processed, an amount of material corresponding to more than 15 000 nuclear warheads. When the original program is completed in 2013, 500 t of HEU will have been eliminated.

The United States has also made substantial progress in downblending its own smaller HEU stockpile. More than 117 t of HEU have been processed, with some of the material used as fuel in nuclear power reactors, and other material set aside as a fuel reserve for other nonproliferation programs.

The amount of HEU in reactors around the world has been considerably reduced under the U.S. government's Global Threat Reduction Initiative. Since May 2004, 18 research reactors have been converted to operate with LEU. In addition, fresh and irradiated HEU fuel stored at reactors around the world has been shipped to the United States and Russia for secure storage and eventual disposal. At the recent Nuclear Security Summit, the leaders of Canada, Mexico, and Ukraine committed to shipping their stocks of HEU to Russia or the United States for secure storage. Nongovernmental organizations have also played an important role. For example, the Nuclear Threat Initiative worked with the government of Kazakhstan to secure and blend down fresh HEU fuel that had been intended for use in a fast reactor that is now shut down.

In the area of plutonium disposition,[22] progress has been less substantial. In 1994, the National Academy of Sciences cited the "clear and present danger" posed by stockpiles of weapons-grade

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plutonium. Sixteen years later, real progress in disposing of plutonium remains elusive. In 2000, Russia and the United States signed an agreement committing each country to dispose of 34 t of weapons-grade plutonium by converting the material to MOX fuel and using it in nuclear power reactors. Plutonium disposition[24] was to have begun in earnest by 2007. That goal was not achieved, but the United States did carry out a MOX fuel lead test assembly program in a commercial reactor, and Russia used MOX fuel lead test assemblies in fast reactors.

For years, the United States insisted that Russia accomplish a significant part of its disposition program using light-water reactors, while Russia preferred to use its weapons-grade plutonium in fast reactors. In conjunction with the recent National Security Summit, the two countries signed an updated plutonium disposition agreement.[3] Like the 2000 agreement, this new arrangement provides for the disposal of 34 t of weapons-grade plutonium by each country. The updated agreement, however, allows Russia to use fast reactors to dispose of its plutonium, provided certain nonproliferation constraints are met. This is an encouraging development that highlights the need to allow countries to pursue nonproliferation and fuel cycle goals in tandem, consistent with Point 2 of PS#55.

Progress on plutonium disposition lags the success of downblending HEU for the following reasons: MOX fuel requires more expensive, specialized facilities for its processing; the transport of the fuel to reactor sites is complicated and more expensive compared with that for uranium oxide fuel; the use of MOX fuel requires changes to current light-water reactor fuel management practices, modifications to nuclear power plants, and contentious licensing proceedings; and the disposal of plutonium using MOX fuel is opposed by some on the grounds that plutonium should not be used even for beneficial purposes.

The construction of a MOX fuel fabrication facility at the Savannah River Site in South Carolina is well under way, but large-scale plutonium disposition in the United States remains the better part of a decade away by the most optimistic schedule. As noted in Point 6 above, "plutonium disposition will require sustained and stable support" if it is going to succeed.

For the future

The continued support of a strong nuclear nonproliferation regime is a vital national security objective for the United States. In order to be effective, U.S. nonproliferation policies must be developed and implemented in a manner that ensures broad and bipartisan national support and carried out with the dedication and constancy that is essential in meeting challenging, long-term objectives.

It is ANS's position that nuclear science and technology can be applied for peaceful purposes in a sustainable energy future compatible with this goal. Moreover, in a world that is experiencing a resurgence of nuclear power, nonproliferation cannot be viewed in isolation. To achieve its nonproliferation goals, the United States must be a player—and, in fact, a leader—not a spectator, when it comes to the peaceful application of nuclear technology.

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