The Challenges of
Fissile Material Control

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The statements, views, and findings in this report are the sole responsibility of ISIS and the authors. They should not be ascribed to any of the aforementioned individuals, institutions, or governments.

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About the Authors

David Albright is a physicist and President of the Institute for Science and International Security (ISIS), in Washington D.C. He has assessed worldwide plutonium and highly enriched uranium inventories since the early 1980s. He is the author of many studies on fissile material and nuclear weapons programs, most notably, with Frans Berkhout and William Walker, of *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies*, published in 1997 by the Stockholm International Peace Research Institute and the Oxford University Press. He received a 1992 Olive Branch Award for a series of articles he co-authored on the Iraqi nuclear weapons program for the *Bulletin of the Atomic Scientists*. In 1996 he was a member of an International Atomic Energy Agency Action Team inspection in Iraq. He serves on the Secretary of Energy's Openness Panel, and, since 1990, on the state of Colorado's Health Advisory Panel overseeing the Historical Public Exposures Studies from Rocky Flats.

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The Institute for Science and International Security (ISIS) is a non-profit, non-partisan institution dedicated to informing the public about science and policy issues affecting international security. Its efforts focus on stopping the spread of nuclear weapons, bringing about greater transparency of nuclear activities worldwide, and achieving deep reductions in nuclear arsenals. ISIS's projects integrate technical, scientific, and policy research in order to build a sound foundation for a wide variety of efforts to reduce the threat posed by nuclear weapons to U.S. and international security.

Glossary

Actinide A heavy, radioactive element with an atomic number greater than 89 (actinium) and less than 103 (lawrencium). The actinide series includes uranium (atomic number 92) neptunium (93), plutonium (94), and americium (95).

Americium A fissionable, artificial element that can be used to produce nuclear explosives. The principal isotope, americium 241, is created as a result of the decay of plutonium 241. Other important isotopes are americium 242m and 243.

Critical mass The minimum mass required to sustain a chain reaction. The exact mass varies with factors such as the particular isotope present, its concentration and chemical form, the geometric arrangement of the material, and its density.

Declared facility A facility that has been declared to the International Atomic Energy Agency (or other inspection authority) and is made available for inspection in accordance with relevant safeguards obligations. In a non-nuclear weapon state party to the NPT, this includes all operating nuclear facilities. In a nuclear weapon state it includes only facilities designated by the state.

De facto nuclear weapon state A non-nuclear weapon state that is not a party to the Nuclear Non-Proliferation Treaty and possesses unsafeguarded nuclear facilities and a nuclear weapons program. Typically refers to India, Israel, or Pakistan.

Depleted uranium Uranium containing less than 0.71 percent uranium 235. Produced as a byproduct of the uranium enrichment process.

Disposition The disposal of plutonium or enriched uranium, especially stocks arising from dismantled nuclear weapons.

Enrichment The process of increasing the concentration of one isotope of a given element (in the case of uranium, increasing the percentage of uranium 235).

Fertile material Material composed of atoms which readily absorb neutrons to produce fissile material. One such material is uranium 238, which becomes plutonium 239 after it absorbs a neutron. Fertile material alone cannot sustain a chain reaction.

Fissionable material Material whose nuclei can be induced to fission by a neutron.

Fissile material Material composed of atoms that fission when irradiated by slow or "thermal" neutrons. The most common are uranium 235 and plutonium 239. The term is often used to describe plutonium and highly enriched uranium, as in the proposed cutoff in the production of "fissile materials." Uranium 233 is also fissile.

Fuel-grade plutonium Plutonium containing from 7 to 18 percent plutonium 240.

Highly enriched uranium (HEU) Uranium in which the percentage of uranium 235 is raised ("enriched") from a natural level of 0.71 percent to greater than 20 percent—usually to 90 percent. All HEU can be used to make nuclear explosives, although a very large quantity is required for HEU enriched to only 20 percent.

Hot cell A shielded room with remote handling equipment where highly radioactive materials can be safely examined and processed. Hot cells are typically used to handle and inspect spent reactor fuel or targets.

Immobilization The process of isolating materials, either directly or indirectly, in a matrix of vitrified high-level nuclear waste. Often refers to a particular plutonium disposition technique.

Isotope Atoms having the same number of protons but a different number of neutrons. Two isotopes of the same atom are chemically similar to each other, and therefore difficult to separate, but they may have different nuclear properties. Isotopes are designated by their atomic mass numbers (total number of protons and neutrons). Uranium 235 and uranium 238 are isotopes.

Low-enriched uranium (LEU) Uranium containing more than 0.71 and less than 20 percent uranium 235. Most modern light-water power reactors use 3–5 percent LEU. LEU is insufficiently enriched in uranium 235 to be used in nuclear explosives.

Material Protection, Control and Accountancy (MPC&A) Systems and procedures that are designed to deter, prevent, and detect the removal of fissile materials by unauthorized personnel.

Mixed Oxide (MOX) Fuel Nuclear fuel composed of a mixture of uranium and plutonium oxide.

Model Protocol A legal instrument containing important aspects of the International Atomic Energy Agency's strengthened safeguards. The Protocol must be ratified by individual states before its measures can be implemented. *See also* strengthened safeguards.

Natural uranium Uranium containing 0.71 percent uranium 235.

Naval propulsion reactor *See* propulsion reactor.

Non-nuclear weapon state Any state that did not manufacture and explode a nuclear weapon or other nuclear explosive device before January 1, 1967. Non-nuclear weapon states that are party to the NPT are obligated to sign comprehensive safeguards agreements with the International Atomic Energy Agency to ensure that declared civil nuclear materials are not being diverted to military purposes, and (under recently strengthened safeguards) to verify the absence of undeclared fissile material production facilities.

Neptunium 237 A fissionable, artificial isotope that can be used to produce nuclear explosives. Neptunium is created by irradiating uranium 235 or uranium 238 in a nuclear reactor or through the decay of americium 241.

Non-weapon state *See* non-nuclear weapon state.

Nuclear weapon state Any state that manufactured and detonated a nuclear weapon or other explosive device before January 1, 1967—specifically, Britain, China, France, Russia (as the successor to the Soviet Union), and the United States.

Plutonium 239 A fissile, artificial isotope created when uranium 238 captures a neutron through irradiation. Plutonium 239 is one of the principal materials used for nuclear weapons; the other is uranium 235.

Plutonium 240 An isotope produced in nuclear reactors when uranium 239, instead of decaying to plutonium 239 or fissioning, absorbs a second additional neutron. Its presence complicates the construction of nuclear explosives because of its high neutron emission and heat output.

Power reactor A nuclear reactor designed to produce electricity, as distinguished from reactors used primarily for research or for the production of radiation or fissionable materials.

Production reactor A nuclear reactor designed principally for the large-scale production of weapon-grade plutonium.

“Programme 93+2” *See* strengthened safeguards.

Propulsion reactor A nuclear reactor configured for the propulsion of naval ships and submarines.

PUREX process A particular method of reprocessing spent fuel. *See also* reprocessing.

Reactor-grade plutonium Plutonium containing more than 18 percent plutonium 240.

Reprocessing The chemical treatment of spent fuel to separate one or more elements (in most cases, plutonium and uranium) from unwanted radioactive byproducts and (under present plans) from each other.

Research reactor A nuclear reactor primarily designed to produce neutrons for research purposes. Such reactors are also used for training, materials testing, and radioisotope production.

Safeguards Technical and inspection measures for verifying that nuclear materials are not being diverted from civil to other uses. *See also* strengthened safeguards.

Separative work A measure of the effort required in an enrichment facility to separate uranium of a given uranium 235 content into two fractions, one with a higher percentage of uranium 235 and one with a lower percentage. The unit of measure is the kilogram separative work unit (SWU).

Significant quantity The approximate amount of nuclear material (not just fissile material) which the International Atomic Energy Agency considers that a state would need to manufacture its first nuclear explosive. Eight kilograms of plutonium and 25 kilograms of weapon-grade uranium are considered significant.

Spent fuel Fuel elements that have been removed from a reactor after use because they contain too little fissile and fertile material and too high a concentration of unwanted radioactive byproducts to sustain reactor operation. Spent fuel is both thermally and radioactively hot.

Strengthened safeguards A set of measures adopted by the International Atomic Energy Agency (IAEA) to better enable IAEA inspectors to verify that states have not initiated clandestine fissile material programs. Developed through “Programme 93+2,” certain aspects of strengthened safeguards are formalized in the Model Protocol.

Tonne A metric ton; equivalent to 1,000 kilograms or 2,200 pounds.

Undeclared facility A nuclear facility that has not been declared to the International Atomic Energy Agency (or other inspection authority). In the non-nuclear weapon states, undeclared facilities may constitute a violation of relevant safeguards agreements.

Uranium 233 A fissile, artificial isotope that can be used to produce nuclear explosives. Created when thorium 232 captures a neutron through irradiation.

Uranium 235 The only naturally occurring fissile isotope. Natural uranium contains only 0.71 percent uranium 235.

Uranium 238 The principal isotope (99.3 percent) of natural uranium.

Weapon-grade plutonium Plutonium containing less than 7 percent plutonium 240.

Weapon-grade uranium Uranium enriched to more than 90 percent uranium 235.

Weapon-grade uranium equivalent (WGU-eq) The amount of weapon-grade uranium (93 percent) that is equivalent to an HEU stock of another enrichment. Often refers to the amount of weapon-grade uranium that could have been produced from the total separative work output, assuming a typical tails of 0.3 percent. This calculation is used when the actual enrichment level of the HEU is unknown, although most of it is believed to be weapon-grade uranium.

Weapon state *See* nuclear weapon state.

Acronyms appearing in the text

CD Conference on Disarmament

CTBT Comprehensive Test Ban Treaty

CTR Cooperative Threat Reduction

DOE Department of Energy (United States)

Euratom European Atomic Energy Community

FMCT Fissile Material Cutoff Treaty

HEU Highly enriched uranium

IAEA International Atomic Energy Agency

INFCIRC Information Circular

ISIS Institute for Science and International Security

IPPE Institute for Physics and Power Engineering (Russia)

LEU Low-enriched uranium

Minatom Ministry of Atomic Energy (Russia)

MOX mixed oxide (reactor fuel)

MPC&A Material Protection, Control and Accountancy

NPT Nuclear Non-Proliferation Treaty

NSG Nuclear Suppliers Group

NWFZ Nuclear-weapon-free zone

PUREX Plutonium/Uranium Extraction process

START Strategic Arms Reduction Talks/Treaty

SPRU Science Policy Research Unit

SWU Separative Work Unit

U.K. United Kingdom

U.N. United Nations

U.S. United States of America

USEC U.S. Enrichment Corporation (United States)

WGU-eq Weapon-grade uranium equivalent

Introduction

The Fissile Material Challenge

Plutonium and highly enriched uranium (HEU), commonly called "fissile materials," are the key ingredients of nuclear weapons, making them two of the most dangerous materials in existence. There are more than 3,000 tonnes (metric tons) of these materials in the world, enough for more than 230,000 nuclear weapons.

Effectively managing, controlling, and disposing of fissile materials is essential to preserving international security and reducing the risk of nuclear war, nuclear proliferation, and nuclear terrorism. The need to reduce the risks posed by these materials has been highlighted by the end of the Cold War, the collapse of the Soviet Union, and revelations about Iraq's pre–Persian Gulf War clandestine nuclear weapons program.

The Challenges of Fissile Material Control evaluates the major efforts now under way to manage, control, and dispose of plutonium and HEU, thereby reducing the risk posed by these materials. Chapter I, by David Albright, grades governments' efforts to control military and civil fissile materials. Although a number of initiatives have begun, only a few have achieved significant progress. The overall pace of creating and implementing the necessary controls has been disappointing. Many initiatives are lagging or have stalled completely.

In a major breakthrough, the Geneva-based Conference on Disarmament (CD) agreed in August to start negotiations toward a fissile material cutoff treaty (FMCT). In Chapter II, William Walker discusses the urgent need for an agreement, and its essential role in complementing and strengthening parallel efforts to declare, verify, and eliminate excess stocks of military fissile materials.

Chapter III, by Kevin O'Neill, surveys several key fissile material initiatives, with an emphasis on those that are necessary to significantly reduce nuclear arsenals and pave the way for nuclear disarmament. This chapter also examines recent and largely successful efforts to strengthen International Atomic Energy Agency (IAEA) safeguards in the non-nuclear weapon states. The process of nuclear reductions will require more stringent measures among non-weapon states to ensure that they are not acquiring nuclear weapons.

Chapter IV, also by O'Neill, finds that both the physical protection and accounting of Russian fissile material stocks remain inadequate, creating significant risk that some weapon-usable fissile material will be diverted. In fact, controls have been so weak during the last several years that one cannot say with assurance that significant quantities of fissile material have not already been diverted. The successful acquisition of fissile material by a terrorist group or a country such as Iraq or Iran could profoundly threaten world security.

The report concludes with a chapter by Albright and Lauren Barbour that considers an issue looming on the horizon, namely the need to institute more controls on two other nuclear explosive materials—neptunium 237 and americium. Although these materials are quietly recognized by the nuclear community as usable in nuclear explosives, the problem has received little public attention. Neither export controls nor materials monitoring currently provide the international community with adequate assurance that these materials are not being used to make nuclear explosives.

The IAEA, concerned by the potential proliferation threat posed by neptunium and americium, is considering monitoring separated neptunium 237 and americium in non-nuclear weapon states. The debate over monitoring these materials could have important implications on export controls, physical protection standards, and nuclear waste disposal practices. It may also affect the negotiation of an FMCT.

The Long Road Ahead

This report makes clear that considerably more effort is needed to bring about a world where the threat from fissile materials is minimized. U.S. and Russian leadership remains critical, yet domestic problems in both countries are undermining effective leadership and further complicating already difficult funding problems for the entire range of fissile-material efforts. To make matters worse, the United States and Russia are also in conflict on several important issues.

No one should underestimate the magnitude of the task. In both the civil and military areas, implementing effective, comprehensive controls is bound to take years. However, these difficulties must not become excuses for endless procrastination. The goal must remain a world safe from the dangers posed by fissile materials.

Despite widespread problems, the initiatives outlined in this report are a sound foundation that can serve as the basis for constructing a robust and adequate system to manage, control, and dispose of both civil and military fissile materials. As David Albright, Frans Berkhout, and William Walker emphasize in *Plutonium and Highly Enriched Uranium 1996*, creating and implementing the full range of fissile material initiatives is not optional. A cutoff in further production of fissile materials for weapons, greater transparency over all stocks, improved safeguards and physical protection, more consistent enforcement of international treaties, more effective export controls, and the ultimate disposal of fissile materials are all necessary. Together, they serve the common interest in preventing nuclear proliferation and terrorism, and in bringing the international community closer to an effective and verifiable control regime to support partial or complete nuclear disarmament.

Throughout the lengthy and difficult process of implementing these initiatives, four guiding principles need to be applied consistently:

Universality. All stocks of fissile material in all countries should be subject to the most exacting standards of accounting, verification, and physical protection.

Transparency. All states should establish and regularly publish summaries of inventories of fissile materials; they should also reveal the infrastructures used to produce them.

Minimization. Stocks of fissile material should be minimized, and excess military stocks should be reasonably defined, then eliminated or disposed of. Military stocks held in "reserves" should be reduced.

Access. International inspection agencies need greater access to facilities and information relevant to nuclear or nuclear-related activities in all states.

The Challenges of Fissile Material Control supplements and partially updates *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities, and Policies* by David Albright, Frans Berkhout, and William Walker. That book provides a detailed discussion of both fissile material stocks and policy initiatives in the areas of military stocks, nuclear nonproliferation, and civil plutonium separation and reuse. It also provides a wider frame of reference for the grades awarded for government efforts to manage, control, and dispose of fissile materials. The reader is also referred to the ISIS website (http://www.isis-online.org) for additional information.

—*The Editors*