# RESOURCE LETTER



## Resource Letter PSNAC-1: Physics and society: Nuclear arms control

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This Resource Letter provides a guide to the literature on nuclear arms control for the nonspecialist. Journal articles and books are cited for the following topics: nuclear weapons, fissile materials, nonproliferation, missiles and missile defenses, verification, disarmament, and the role of scientists in arms control. 
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### I. INTRODUCTION

Arms control as a significant technical discipline emerged in the 1950s and 1960s out of a growing realization of the profound dangers posed by the U.S.-Soviet nuclear arms race and the threat of nuclear war. A clear early expression of this perspective was provided by Thomas Schelling and Morton Halperin in a seminal 1961 work, *Strategy and Arms Control* (Ref. 100), in which they proposed that "arms control … rests essentially on the recognition that our military relation with potential enemies is not one of pure conflict and opposition, but involves strong elements of mutual interest in the avoidance of a war that neither side wants, in minimizing the costs and risks of the arms competition, and in curtailing the scope and violence of war in the event it occurs." (p. 1)

The goal of arms control became to find mutually agreeable, often incremental steps that would curtail the arms race while maintaining stability, and so reduce tensions and build confidence among the superpowers. The search for such steps created an important channel for dialogue between the superpowers, even during crises. It was also a way for governments of both superpowers to reassure their domestic publics and the international community that they too were concerned about the need to reduce the costs, risks, and consequences of their very large arsenals, and attendant nuclear postures, strategies, and policies. The need to discuss arms-control measures created an important channel for dialogue between the superpowers.

Efforts to agree on limits on the sizes of the nuclear arsenals have been largely confined to the United States and the Soviet Union, now Russia. The other nuclear-armed states bound by the 1970 Nuclear Non-proliferation Treaty (NPT) to eliminate their weapons—Britain, France, and China—have either taken unilateral arms-control steps or joined multinational arms-control treaties that also include non-nuclear weapons states. They have not yet engaged in arms-control talks with the United States and Russia on reductions in arsenals. It is widely assumed that this will have to happen when the United States and Russia reduce their arsenals to 1000 warheads or fewer.

There are several abiding issues that have been the concern of the nuclear arms-control community for the past half century and will be the focus of this Resource Letter. The first is to understand and explain the effects of nuclear weapons and to limit their further development through a ban on nuclear testing. A limited ban on nuclear tests in the atmosphere, at sea, and in space was agreed to in 1963. This largely dissipated the public opposition to nuclear testing, which had focused in particular on the large releases of radioactivity that accompanied above-ground testing. Nuclear testing continued below ground. A Comprehensive Test Ban Treaty, banning all nuclear tests, was negotiated in 1996. It has not yet entered into force. However, there are questions about how significant a constraint this treaty is on the development of new nuclear weapons by states with advanced weapons programs.

A second major concern has been to control the production of fissile material—highly enriched uranium and plutonium—for nuclear weapons. The U.N. General Assembly in 1957 proposed a treaty that would have ended the production of fissile materials for weapons purposes and limited all future production to nonweapons purposes under international control. However, a Fissile Material Cutoff Treaty has not yet been negotiated, although most nuclear-armed states stopped production of highly enriched uranium and plutonium for weapons some time ago.

The development of ballistic missiles able to carry nuclear weapons over intercontinental distances in a few tens of minutes created a new sense of vulnerability, dramatically changed the dynamics of the nuclear arms race, and engendered efforts to create missile defenses. The search for defenses led in turn to a search for countermeasures, including mounting multiple warheads on ballistic missiles and multiple cruise missiles on bombers to overwhelm defenses. Arms-control analysts have sought to offer a way out of this spiral by showing the limited efficacy of defensive systems.

The mistrust between the United States and the Soviet Union strengthened by their respective nuclear arsenals and policies, ensured that a critical challenge for arms-control agreements has been the question of verification. While many technical options may exist for determining compliance with any particular commitment, their feasibility is typically constrained by the interests of each state in keeping secret the information on their nuclear weapons and capabilities. Policy makers, nuclear-weapons bureaucracies, and military leaders have at times exaggerated security concerns as a way to prevent arms control.

The end of the Cold War and collapse of the Soviet Union, now almost 20 years ago, transformed the global landscape for arms control. In the absence of confrontation, arms-control critics in the United States in particular felt that there was no longer a need to accept constraints on strategic capabilities. For many people, the end of the Cold War meant an end to the nuclear arms race and the lifting of the threat of nuclear war. These factors led to a reduced interest in arms control and nuclear disarmament, despite that the United States and Russia retain over 10,000 nuclear weapons each, with many deployed on hair-trigger alert and large stocks of fissile materials; in both countries there are calls for new kinds of nuclear weapons.

Recently, however, interest has grown again in arms control and the urgent need to chart a path to the elimination of nuclear weapons. This has been due in large part to the belated recognition among the arms-control community and U.S. policy makers—laid out most clearly in a January 2007 op-ed in the Wall Street Journal by George Shultz, William Perry, Henry Kissinger, and Sam Nunn—that unless there is a global ban on nuclear weapons "the U.S. soon will be compelled to enter a new nuclear era that will be more precarious, psychologically disorienting, and economically even more costly than was Cold War deterrence."

This new sensibility among policy makers is a response to proliferation of nuclear-weapons programs over the past two decades to third-world states, most notably Iraq, North Korea, and possibly Iran, the Indian and Pakistani nuclear tests of 1998, the need to secure fissile materials and expertise from the former Soviet Union's nuclear-weapons complex, and, after the attacks of September 11, 2001, the threat of nuclear weapons in the hands of terrorist groups. There is a rich literature on these issues, but much of it is of a nontechnical nature or is country specific. It is not referenced at length in this Resource Letter. Instead, we focus on introducing basic ideas about the science and technology that underlies all such nuclear-weapons programs and the monitoring of nuclear activities.

There are a number of crucial areas where there has been little effort at arms control; these are not discussed here. There are agreements to limit the numbers of deployed systems, but there has been no significant progress in controlling or eliminating entire classes of delivery systems. This is despite that the stated goal of the 1970 NPT is the elimination of nuclear weapons and the means of their delivery. Similarly, apart from the 1967 Outer Space Treaty banning the placing of nuclear weapons in orbit, on celestial bodies, or in outer space, there have been no constraints on the military uses of space. There are now concerns about U.S. plans to place weapons in space and develop the capacity to wage war from space-based platforms. This will likely become an active area of future arms-control research.

Two earlier Resource Letters overlap some of the topics covered here, as follows:


**1.** "Resource Letter PNAR-1: Physics and the Arms Race," D. Schroeer and J. Dowling, Am. J. Phys. **50**(9), 786–795 (1982). (E)

**2.** "Resource Letter MP-1: The Manhattan Project and related nuclear research," B. Cameron Reed, Am. J. Phys. **73**(9), 805–811 (2005). (E)


## II. JOURNALS

There are many journals devoted to nuclear arms control, but most are oriented towards current policy issues.

Technical arms-control journals

*Science & Global Security*

Arms-control policy journals

*Arms Control Today*
*Bulletin of the Atomic Scientists*
*INESAP Information Bulletin*
*Disarmament Diplomacy*
*Nonproliferation Review*

General international-relations journals, periodicals, and paper series with regular arms-control policy articles

*Adelphi Papers*
*International Security*
*Foreign Affairs*
*Survival*

Specialist nuclear-industry journals with occasional news and articles relevant to arms control

*Nuclear Fuel*
*Nucleonics Week*
*Journal of Nuclear Materials Management*

General science journals with occasional arms-control articles

*Physics Today*
*Scientific American*
*Science*
*Nature*

Newsletters

*APS Physics & Society Newsletter*
*FAS Public Interest Report*

## III. TEXTBOOKS AND REFERENCE BOOKS

The issues raised by the existence of nuclear weapons and the struggles to control and eliminate them have generated a vast literature over the past 60 years. Some of the basic requirements for thinking systematically about arms control are knowledge about the development and status of nuclear-weapons programs, the technologies and processes associated with them, and the repertoire of arms-control ideas, agreements, and technical options.


3. **Deadly Arsenals: Nuclear, Biological, and Chemical Threats**, J. Cirincione, J. B. Wolfsthal, and M. Rajkumar, 2nd ed. (Carnegie Endowment for International Peace, Washington, DC, 2005). An assessment of global trends and data concerning the spread of weapons of mass destruction with a strong emphasis on nuclear-weapon issues. It includes overviews of nuclear-weapon programs and topical country case studies. It can serve as a reference or textbook for introductory and intermediate-level courses. (E)
4. **Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940**, edited by S. I. Schwartz (Brookings Institution, Washington, DC, 1998). This pathbreaking study documents the economic, political, environmental and public-health costs of the U.S. nuclear weapons program from 1940 to1996. It serves as a guide for understanding the basic structure and dynamics of nuclear-weapons programs, how such programs can overwhelm policy making processes, and the limits and opportunities for arms-control initiatives. (I, A)
5. **SIPRI Yearbook, Stockholm International Peace Research Institute** (Oxford U. P., New York, 2007). The authoritative source on security and conflicts, military spending and armaments, and nonproliferation, arms control, and disarmament. Each volume also includes a number of appendices on special topics, often relevant to nuclear arms control, including an annual inventory and commentary on the nuclear forces of the various states. (I)
6. **Arms Control: The New Guide to Negotiations and Agreements**, J. Goldblat (Sage, London, 2002). This is the most comprehensive source on arms-control talks and treaties over the past century. It includes analysis of the negotiations and the final treaties. A CD supplement contains full texts of the treaties and associated resources. (A)


### *Technical Aspects*


7. **Physics of Societal Issues: Calculations on National Security, Environment and Energy**, D. Hafemeister (Springer, Berlin, 2007). The scope of this volume is broad, but five chapters are dedicated to the physics of nuclear weapons, arms control, and proliferation. There are extensive problem sets for each section. The articles that are the basis for major parts of this book were first published in the AJP in the 1980s. (I, A)
8. **Science, Technology, and the Nuclear Arms Race**, D. Schroeer (J. Wiley, New York, 1984). A comprehensive technical survey of the nuclear arms race, covering nuclear weapons and their effects, delivery systems, defenses, arms control, and disarmament. There is an associated Teachers Manual, with sample calculations, problems sets, examination questions, and additional references. Some discussions that relate to specific military technologies or aspects of the Cold War are no longer as relevant as they were—but this monograph remains unequaled. (I, A)
9. **Arsenal: Understanding Weapons in the Nuclear Age**, K. Tsipis (Simon and Schuster, New York, 1983). An exposition of the basic principles underlying nuclear weapons and their effects, ballistic and cruise missiles, and missile defenses. The 13 technical appendices make this volume suitable also for readers with more background in physics and mathematics. (E, I)
10. **Nuclear Choices: A Citizens Guide to Nuclear Choices**, R. Wolfson, revised edition (MIT, Cambridge, MA, 1995). A thorough nontechnical introduction to the science and technology of nuclear energy and nuclear weapons, with a glossary of technical terms and bibliography. (E)
11. **Megawatts and Megatons: A Turning Point in the Nuclear Age**, R. L. Garwin and G. Charpak (Knopf. New York, 2001). A wide-ranging and personal reflection by a leading American arms-control physicist and a French Nobel Laureate on many of the key concepts and questions about nuclear weapons, nuclear energy, and the role of scientists in informing policy choices. It offers an engaging introduction to all three issues. (E)
12. **Nuclear Energy**, D. Bodansky, 2nd ed. (Springer/AIP, New York, 2004). A modern introduction to nuclear energy, emphasizing principles, practices, and prospects of the technology. Includes two chapters on nuclear weapons and proliferation. (E, I)
13. **Nuclear Chemical Engineering**, M. Benedict, T. H. Pigford, and H. W. Levi, 2nd ed. (McGraw-Hill, New York, 1981). The authoritative technical reference on the nuclear-fuel cycle. It discusses the major reactor concepts, nuclear fuel types, and related processing technologies, with an extensive quantitative treatment of reprocessing and enrichment technologies for the advanced reader. The book is out of print and hard to find. (A)
14. **Nuclear Forensic Analysis**, K. J. Moody, I. A. Hutcheon, and P. M. Grant (Taylor & Francis, CRC, Boca Raton, 2005). An excellent discussion of the physical basis and methods for the characterization of nuclear materials. The techniques described here are especially relevant to the identification of the source and processing history of sampled materials, covering in particular fissile material production, separation, isotopics, and aging. Several case studies illustrate the available methods. (A)
15. **Managing Nuclear Operations**, edited by A. B. Carter, J. D. Steinbruner, and C. A. Zraket (Brookings Institution, Washington, DC, 1987). The technical resource for understanding operational details of how U.S. nuclear forces are structured, controlled, and would be used, and an analysis of the attendant policy implications, many of which are directly relevant to arms control. (A)


## IV. SPECIFIC TOPICS

References on specific topics are categorized as follows: nuclear weapons, fissile materials, missiles and missile defenses, arms-control verification, disarmament, and the role of scientists in the arms-control process.

### A. Nuclear weapons

This Resource Letter largely omits references on the history of nuclear weapons, their development, and their military and political significance during and after the Cold War. There is an extensive and important literature on the histories of all major nuclear-weapons programs, and in particular on the U.S. Manhattan Project. The reader may refer to the aforementioned “Resource Letters MP-1: The Manhattan Project and related nuclear research” and “PNAR-1: Physics and the Arms Race” for a comprehensive collection of references on this specific topic.


16. **Atomic Energy for Military Purposes: The Official Report on the Development of the Atomic Bomb Under the Auspices of the United States Government, 1940–1945**, H. D. Smyth (Princeton U. P., Princeton, NJ, 1945). A contemporary account of the scientific and technological aspects of the building of the first nuclear weapon. It offers useful insights into the status of knowledge at the time and the organization of the program. (E, I)
17. **Nuclear Weapons Databook Series, Volume I: U.S. Nuclear Forces and Capabilities**, T. B. Cochran, W. M. Arkin, R. S. Norris and M. M. Hoenig (Ballinger, Cambridge, MA, 1984). This is the first volume of the nuclear-weapons databook series compiled by the Natural Resources Defense Council (NRDC) in the 1980s and early 1990s. This series remains the authoritative and most extensive technical resource on this topic. Copies of individual volumes can be ordered directly from ⟨www.nrdc.org⟩. (I)
18. **Nuclear Weapons Databook Series, Volume IV: Soviet Nuclear Weapons**, T. B. Cochran, W. M. Arkin, R. S. Norris and J. I. Sands (Ballinger, Cambridge, MA, 1989). (I)
19. **Nuclear Weapons Databook Series, Volume V: British, French and**

**Chinese Nuclear Weapons**, R. S. Norris, A. Burrows, and R. Fieldhouse (Ballinger, Cambridge, MA, 1994). (I)

Information on the history of nuclear-weapons programs in other states generally remains less well documented. Remarkable exceptions are:

**20.** **Israel and the Bomb**, A. Cohen (Columbia U. P., New York, 1998). (I)

**21.** **India's Nuclear Bomb**, G. Perkovich (Univ. of California, Berkeley, 1999). (I)

### *Principles of Nuclear Weapons*

**22.** "The Fission Bomb" and "The Fusion Bomb," Chaps. 2 and 3 in **Science, Technology, and the Nuclear Arms Race**, D. Schroeer (Ref. 8). Starts with simple discussions of the nuclear-fission and fusion processes and presents the basic nuclear-weapon principles on an introductory level. These chapters also touch briefly on other aspects, including nuclear-weapons effects, which are listed separately below. (E)

**23.** "Nuclear Weapons," Chap. 1 in **Physics of Societal Issues**, D. Hafemeister (Ref. 7). Similar in scope, but somewhat more technical than the respective discussion in Schroeer (Ref. 8). (I)

**24.** **The Los Alamos Primer: The First Lectures on How to Build an Atomic Bomb**, R. Serber (Univ. of California, Berkeley, 1992). Annotated reprint of five lectures on nuclear-weapon design prepared and given by the author at Los Alamos in April 1943, that is before the high spontaneous-fission rate of plutonium was discovered, which required the development of the implosion method. It includes a derivation of expressions to estimate the yield of a nuclear weapon. (A)

**25.** "Estimate of the critical mass of a fissionable isotope," E. Derringh, Am. J. Phys. **58**(4), 363–364 (1990). This short article presents a simple analytical method for estimating a bare spherical critical mass (the amount of material needed to sustain a nuclear-chain reaction), using uranium-235 as the numerical example. (E, I)

**26.** "Explosive Properties of Reactor-Grade Plutonium," J. C. Mark, F. von Hippel, and E. Lyman, Sci. Global Secur. **4**(1), 111–124 (1993). Coauthored by the former director of the Theoretical Division of Los Alamos National Laboratory, J. C. Mark, this article shows that reactor-grade plutonium can be used to construct a nuclear explosive device—a fact that had been long disputed. An appendix details how the probable yield of a plutonium-based nuclear-weapon detonation depends upon the isotopic composition. (A)

**27.** "Third Generation Nuclear Weapons," T. B. Taylor, Sci. Am. **256**(4), 30–39 (1987). A preeminent U.S. nuclear-weapons designer explores the possibilities for new types of nuclear weapons that selectively enhance certain energy types and direct destructive power in specific directions. Also includes a valuable description of nuclear-weapon physics. (I)

**28.** **The Curve of Binding Energy: A Journey into the Awesome and Alarming World of Theodore B. Taylor**, J. McPhee (Farrar, Straus and Giroux, New York, 1974). An easy-to-read introduction to the life and work of a nuclear-weapons designer, with descriptions of some key ideas in nuclear-weapons design and effects, and the need for controls. (E, I)

### *Effects*

The destructive effects of nuclear weapons are difficult to convey. Detailed descriptions of the physical effects, but generally also discussions of biological, medical, or societal effects of nuclear explosions, are insufficient to do so. Yet, the literature—and the list below is no exception—focuses almost exclusively on these phenomena. To account for and emphasize the human dimensions of nuclear-weapon use, we include personal and literary accounts of the bombing of Hiroshima and Nagasaki.

**29.** **Hiroshima**, J. Hersey (Knopf, New York, 1946). First published as a special issue of *The New Yorker* magazine, this remains one of the seminal descriptions of the effects of the U.S. atomic bombing of Hiroshima as told through the experiences of six survivors. (E)

**30.** **Hiroshima. Three Witnesses**, edited by R. H. Minear (Princeton U. P., Princeton, NJ, 1990). A collection of first-person accounts of three survivors of the Hiroshima bombing, originally written and published between 1945 and 1952. The text is complemented by indispensable introductions by the editor, who also translated the original texts from Japanese. (E)

**31.** **The Effects of Nuclear Weapons**, S. Glasstone and P. J. Dolan (U.S. Government Printing Office, Washington, DC, 1977). Out-of-print but available online at ⟨www.ipfmlibrary.org/gla77.pdf⟩. This exhaustive monograph summarizes the knowledge on nuclear-weapons effects gathered in atmospheric and underground U.S. tests. Almost exclusive emphasis on physical effects and damage; one chapter on biological effects. (A)

**32.** **Bombing Bombay? Effects of Nuclear Weapons and a Case Study of a Hypothetical Explosion**, M. V. Ramana, International Physicians for the Prevention of Nuclear War (IPPNW, Cambridge, MA, 1999), ⟨www.ippnw.org⟩. Based upon the methodologies developed in Glasstone and Dolan (Ref. 31), this work considers a concrete case study and shows in a transparent way how to estimate not only physical damage, but also civilian casualties from the detonation of a single low-yield weapon over a large metropolitan area. (I)

**33.** **The Medical Implications of Nuclear War**, edited by F. Solomon and R. Q. Marston (National Academy, Washington, DC, 1986). This comprehensive volume includes detailed discussions of environmental effects (including super-fires and nuclear winter, both of which entered the debate at that time), health consequences, and medical resource needs and availability following a nuclear war. (I, A)

**34.** **The U.S. Nuclear War Plan. A Time for Change**, M. G. McKinzie, T. B. Cochran, R. S. Norris, and W. M. Arkin (Natural Resources Defense Council, Washington, DC, 2001). An independent assessment of the U.S. nuclear war plan and its consequences. A computer model using publicly available and declassified data and Department of Defense computer codes for nuclear-weapons effects is used to simulate a U.S. attack against Russian nuclear forces and cities. A mathematical appendix gives the equations for evaluating nuclear-weapons effects. (E, I)

**35.** "Climatic consequences of regional nuclear conflicts," A. Robock, L. Oman, G. L. Stenchikov, O. B. Toon, C. Bardeen, and R. P. Turco, Atmos. Chem. Phys. **7**, 2003–2012 (2007). This article examines the consequences of several nuclear-war scenarios using a modern climate model. It shows that 100 Hiroshima-sized (15 kt each) nuclear explosions could produce unprecedented and long-lasting global-climate change, with severe impacts on food supply. (A)

**36.** "Nuclear Bunker Busters, Mini-Nukes, and the US Nuclear Stockpile," R. W. Nelson, Phys. Today, **56**(11), 32–37 (2003). A review article of the technical reasons why low-yield (5 kt) nuclear weapons cannot be used as earth penetrators to destroy deeply buried hardened targets without producing large amounts of nuclear fallout, and why such weapons cannot effectively destroy stocks of biological and chemical agents. For greater detail, see the following two references. (I)

**37.** "Low-Yield Earth-Penetrating Nuclear Weapons," R. W. Nelson, Sci. & Global Secur. **10**(1), 1–20 (2002). (A)

**38.** "Nuclear 'Bunker Busters' Would More Likely Disperse than Destroy Buried Stockpiles of Biological and Chemical Agents," R. W. Nelson, Sci. Global Secur. **12**(1-2), 69–90 (2004). (A)

**39.** "The Hazard from Plutonium Dispersal by Nuclear-warhead Accidents" S. Fetter, and F. von Hippel, Sci. Global Secur. **2**(1) 21–41 (1990). This paper assesses the effects of an incomplete detonation of a nuclear weapon, in which it fails to initiate a chain reaction and produces instead a fissile material aerosol. The methodology is also applicable to estimate the consequences of radiological-weapon explosions. (A)

**40.** "Radioactive Carbon from Nuclear Explosions and Non-threshold Biological Effects," A. Sakharov, Sci. Global Secur. **1**(2), 175–187 (1990), and "Revisiting Sakharov's Assumptions," F. von Hippel, Sci. Global Secur. **1**(2), 185–187 (1990). A reprint of a classic 1958 article and modern reassessment showing that there would be about 10,000 deaths

and casualties from the low-dose radiation released from each megaton of atmospheric nuclear tests. (A)

41. **Whole World on Fire: Organizations, Knowledge, and Nuclear Weapons Devastation**, L. Eden, Cornell Studies in Security Affairs (Cornell U. P., Ithaca, NY, 2005). Traditionally U.S. nuclear-war planning has focused on the damage caused by the blast generated by an explosion. This book explores how military planners and organizations have overlooked for decades the devastating effects of superfires, which could accompany nuclear explosions in urban areas and result in a two- to fourfold increase in fatalities. (A)

### *Nuclear Weapon Tests*

Historically, testing has been a critical element of the development process of new nuclear-weapon designs. Limiting or prohibiting nuclear testing has therefore long been recognized as an effective arms-control measure. Respective efforts culminated in the negotiation of the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT). As of June 2007, the treaty has been signed by 177 and ratified by 138 states. The treaty cannot enter into force until a group of 44 states considered to have nuclear-weapon-relevant expertise ratify it. So far, only 38 of these have done so. The United States has signed but not ratified the CTBT and is debating a program to develop a new generation of nuclear weapons that, proponents argue, may not need to be tested before deployment.

42. **Seismic Verification of Nuclear Testing Treaties**, Office of Technology Assessment, OTA-ISC-361 (U.S. Government Printing Office, Washington, DC, 1988). A useful introduction to the science and technology of detecting and discriminating nuclear explosions from earthquakes using seismic methods. (I)

43. **The Containment of Underground Nuclear Explosions**, Office of Technology Assessment (U.S. Government Printing Office, Washington, DC, 1989). An introduction to underground nuclear-weapons testing and the possibilities of containing the release of radioactivity to the surface. Detecting such releases is now an important monitoring tool for the Comprehensive Test Ban Treaty. (I)

44. "Technical Issues of a Nuclear Test Ban," S. Drell and B. Peurifoy, Annu. Rev. Nucl. Part. Sci. **44**, 285–327 (1994). A review of the technical arguments put forward against a CTBT, with an extensive discussion of accidents involving nuclear weapons and the safety features of modern nuclear warheads. (A)

45. **Basic Facts: The Global Verification Regime and the International Monitoring System**, Booklet 3, Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO, Vienna, 2001) available at ⟨www.ctbto.org⟩. An accessible introduction to the CTBT monitoring system. (E)

46. **Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty**, Committee on Technical Issues Related to Ratification of the Comprehensive Nuclear Test Ban Treaty, National Academy of Sciences (National Academy, Washington, DC, 2002). Released after the U.S. Senate voted not to ratify the CTBT, this report provides an authoritative assessment of the verifiability of the treaty, discusses evasion options for clandestine testing and what could be learned from such clandestine testing. The report concludes that, on balance, a CTBT would be in the interests of the United States. (I)

47. "Comprehensive Nuclear-Test-Ban Treaty CTBT Verification," M. B. Kalinowski, pp. 135–152 in **Verifying Treaty Compliance**, edited by R. Avenhaus, N. Kyriakopoulos, M. Richard, and G. Stein (Springer, Berlin, 2006). (A)

48. "Transparency Measures for Subcritical Experiments Under the CTBT," S. L. Jones and F. von Hippel, Sci. Global Secur. **6**(3), 291–310 (1997). (A)

49. "The Question of Pure Fusion Explosions Under the CTBT," S. L. Jones and F. N. von Hippel, Sci. Global Securi. **7**(2), 129–150 (1998). An analysis of possible fusion weapons that would not rely on a fission-weapon trigger, and whose development might therefore be less constrained by the Comprehensive Test Ban Treaty. (A)

50. "The Effects of Nuclear Test-Ban Regimes on Third-Generation-Weapon Innovation," D. L. Fenstermacher, Sci. Global Secur. **1**(3-4), 187–223, (1990). An assessment of three nuclear-weapons concepts (x-ray lasers, nuclear kinetic-energy weapons, and nuclear microwave weapons) and how their development could be limited by a nuclear-weapons test ban that permitted very low-yield tests. (A)

## B. Fissile Materials

Fissile materials are nuclear materials that can sustain an explosive fission chain reaction. They are required for all nuclear-weapon designs, from first-generation fission weapons to modern thermonuclear weapons. The most common fissile materials are plutonium and highly enriched uranium, and controlling these materials can play an important role in nuclear arms control. In this context, technical analysis is required to estimate historic or current production capabilities, to verify nondiversion or nonproduction of fissile material, and to identify viable disposition strategies for existing stocks.

### *General*

51. **Plutonium and Highly Enriched Uranium 1996. World Inventories, Capabilities and Policies**, D. Albright, F. Berkhout, and W. Walker, SIPRI Monographs (Oxford U. P., Oxford, 1997). The authoritative and most comprehensive analysis of global fissile-material inventories up to 1996. Includes valuable discussions of methodologies required to estimate production capabilities and to understand uncertainties of these estimates. Also provides overviews of the technical history of the main nuclear-weapon programs. Post-1996 developments have to be found in other sources. (I)

52. **Global Fissile Material Report**, International Panel on Fissile Materials (International Panel on Fissile Materials, Princeton, NJ, 2006), ⟨www.ipfmlibrary.org/gfmr06.pdf⟩. These annual reports summarize and develop the technical basis for policy initiatives to reduce—and if possible to eliminate—stocks of nuclear-weapon materials worldwide. (I)

53. **MCNP—A General Monte Carlo N-Particle Transport Code**, Version 5 (Los Alamos National Laboratory, 2006). The state-of-the-art computer code to model particle transport in arbitrary three-dimensional geometries and materials. This code has evolved into an indispensable tool for nuclear analysts as it can be used for diverse applications including criticality safety, reactor analysis, and radiation shielding. The software package can be ordered from ⟨www-rsicc.ornl.gov⟩ (for U.S. and Canadian users) and from ⟨www.nea.fr⟩ (for all other users). Export control regulations apply. (A)

### *Production*

Production of plutonium and highly enriched uranium is based upon two fundamentally different processes. Plutonium can be produced in dedicated production reactors, typically fueled with natural uranium, but is also generated as a by-product during routine operation of commercial reactors. Highly enriched uranium can be produced using isotope-separation techniques, in which the U-235 is enriched to very high fractions (typically 90% and higher compared to 0.7% in natural uranium or to 4%–5% in low-enriched fuel used for most power reactors).

54. **The Politics and Technology of Nuclear Proliferation**, R. F. Mozley (Univ. of Washington, Seattle, WA, 1998). As its title indicates, the scope of the book is broader, but Chaps. 3 and 4 provide a good

overview of plutonium production in nuclear reactors and uranium enrichment on an elementary level. (E)

55. **Uranium Enrichment and Nuclear Weapon Proliferation**, A. S. Krass, P. Boskma, B. Elzen, and W. A. Smit (Taylor & Francis, London, 1983). The most comprehensive analysis of proliferation susceptibility of different uranium enrichment technologies used in the commercial nuclear-power sector. Includes overviews of national enrichment programs (as of the early 1980s) and a discussion of political frameworks to address proliferation concerns. The book is out of print but is available electronically at ⟨www.sipri.org⟩. (I, A)

56. "The Gas Centrifuge," D. R. Olander, Sci. Am. **239**(2), 37–43 (1978). This article lays out the basic concepts of the modern gas centrifuge for uranium enrichment and includes a historical overview of its development. (I)

57. "Nuclear Fuel Reprocessing," H. McFarlane, in **Encyclopedia of Energy** (Elsevier, Oxford, 2004), Vol. 4, pp. 351–364. An introductory description of the main reprocessing technology (PUREX) with a brief discussion of existing commercial reprocessing facilities and national policies. (E)

58. **Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to their Environmental Consequences**, Office of Environmental Management, DOE, EM-0319 (U.S. Department of Energy, Washington, DC, 1997). A detailed description of the production facilities and processes of the U.S. nuclear-weapons program, and their environmental impacts. The appendices are very useful technical summaries of the major production processes and apply to a large degree to other such programs. (E, A)

59. **Plutonium: The First 50 Years—Plutonium production and utilization, 1944–1994**, DOE, DP-0137 (U.S. Department of Energy, Washington, DC, 1996). The U.S. declaration of its production and use of plutonium for nuclear weapons. An important resource for understanding the history of the U.S. nuclear-weapons program—and a model for similar declarations by other nuclear-weapons states. (A)

60. **Highly Enriched Uranium: Striking A Balance—A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities, 1945–1996**, Revision 1 (U.S. Department of Energy, Washington, DC, 2001). The unclassified U.S. declaration of its production and use of highly enriched uranium for nuclear weapons and other military or civilian purposes. An important resource for understanding the flows of fissile material through the nuclear complex. Counterpart to **Plutonium: The First 50 Years** (Ref. 59). (A)

### *Disposition of Fissile Materials*

Disposition of fissile materials first became an issue with the end of the Cold War, when the United States and Russia began to declare large amounts of highly enriched uranium (HEU) and weapon-grade plutonium as exceeding their military needs. Fissile materials are also present in the civilian nuclear fuel cycle and therefore risk diversion or theft of the material by state or substate actors. Two cases are most relevant: the use of highly enriched uranium to fuel research reactors and the separation of plutonium from spent fuel in order to fabricate it into nuclear fuel. In principle, disposition of HEU is technically straightforward and economically attractive because it can be blended-down to low enrichment and be used as fuel in nuclear-power plants. Plutonium disposition, on the contrary, is costly and has proven difficult to implement.

61. "Global Cleanout: Reducing the Threat of HEU-fueled Nuclear Terrorism," A. Glaser and F. von Hippel, Arms Control Today **36**(1), 18–23 (2006). A review of the need for and current efforts to eliminate highly enriched uranium from the civilian fuel cycle. (E)

62. "A Comprehensive Approach to Elimination of Highly Enriched-Uranium from all Nuclear-Reactor Fuel Cycles," F. von Hippel, Sci. Global Secur., **12**(3), 137–164 (2004). Highly enriched uranium, which can be used to make simple gun-type nuclear weapons, such as the untested design used to destroy Hiroshima, is in wide use today for fueling civil and military research reactors and naval propulsion. This paper outlines the options for ending reliance on such uses of HEU. (A)

63. **Management and Disposition of Excess Weapons Plutonium**, Committee on International Security and Arms Control (National Academy of Sciences, Washington, DC, 1994–1995). Two volumes, the second one (1995) on **Reactor-Related Options**. This landmark study explores disposition options for plutonium with a strong emphasis on security aspects. Its recommendations laid the basis for all subsequent disposition efforts. (I)

64. "Storage MOX: A Third Way for Plutonium Disposal?" J. Kang, F. von Hippel, A. MacFarlane, and R. Nelson, Sci. Global Securi., **10**(2), 85–101 (2002). A proposal for disposing of separated plutonium as plutonium-uranium oxide pins mixed in among radioactive spent fuel pins in dry-storage casks. This idea was originally suggested in the mid-1990s by the Institute of Applied Ecology in Germany, but not published in English. (A)

65. **Securing the Bomb**, M. Bunn and A. Wier, Project on Managing the Atom, Harvard University, Cambridge, MA (2006) and Nuclear Threat Initiative ⟨www.nti.org⟩. An annual survey, starting in 2002, of the technical and political progress, problems, and proposals associated with securing the fissile materials that can be used to make nuclear weapons. (I)

### *Fissile Material Cutoff Treaty*

The idea of a treaty requiring the "cessation of the production of fissionable materials for weapons purposes" goes back to a 1957 resolution of the U.N. General Assembly. A related resolution adopted in 1993 recommended beginning negotiations of such a treaty. It has been stalled at the Conference on Disarmament in Geneva. Draft treaty texts tabled by Non-Governmental Organizations (NGOs) or individual governments are collected at the website of the International Panel on Fissile Materials ⟨www.fissilematerials.org⟩.

66. United Nations General Assembly Resolution 1148 (XII), "Regulation, limitation and balanced reduction of all armed forces and all armaments; conclusion of an international convention (treaty) on the reduction on armaments and the prohibition of atomic, hydrogen and other weapons of mass destruction," 716th plenary meeting, 14 November 1957, available at ⟨www.un.org⟩. (E)

67. "A Fissile Material Cutoff Treaty," Chap. 5 in **Global Fissile Material Report 2006** (Ref. 52). An excellent overview of the background and issues that will be in contention in the negotiations of a possible fissile material treaty. (E)

68. "A Cutoff in the Production of Fissile Material," F. Berkhout, O. Bukharin, H. Feiveson, and M. Miller, Int. Securi. **19**(3), 167–202 (1994). Inspired by the 1993 U.N. Resolution, this article reviews the contested issues related to the scope and verification of a fissile-material cutoff treaty, and evaluates the benefit and costs of such a treaty to the nuclear-weapon states. (A)

### *Nuclear Proliferation*

The dual-use character of nuclear technology has been recognized from the outset of the atomic era. Since then, analysts have debated the relative importance of the political and technical dimensions of the proliferation process. The discussion is relevant to arms-control efforts, in particular because it will play an important role in the process of strengthening the nonproliferation regime and in negotiating a fissile material cutoff treaty.

69. "Technical Aspects of Nuclear Proliferation," Chap. 4 in **Technologies**

**Underlying Weapons of Mass Destruction**, Office of Technology Assessment, OTA-BP-ISC-115 (U.S. Government Printing Office, Washington, DC, 1993), now available at ⟨www.wws.princeton.edu/ota⟩. A basic introduction to the science and technology associated with setting up a small nuclear-weapons program. The book also covers chemical and biological-weapons programs. (E)

**70.** "Nuclear Proliferation and Diversion," H. A. Feiveson, in **Encyclopedia of Energy** (Elsevier, Oxford, 2004), Vol. 4, pp. 433–447. This article reviews the concept of proliferation resistance, which includes both technical and institutional measures to make the process of proliferation more difficult, time consuming, and visible. Also includes a discussion of technical routes to nuclear weapons and the current system of international safeguards. (I)

**71.** "Civilian Nuclear Technologies and Nuclear Weapons Proliferation," J. P. Holdren, Chap. 10 in **New Technologies and the Arms Race**, edited by C. Schaerf, B. H. Reid, and D. Carlton (St. Martin's, New York, 1989). This analysis examines the links between civilian and military nuclear technologies. Factors that favor or discourage nuclear-weapon acquisition using dedicated military versus nuclear-energy facilities are identified and discussed. (I, A)

**72.** "Nuclear Power and Nuclear Weapons," T. B. Taylor, written in 1996 and reprinted in Sci. Global Securi., **13**(1-2), 118–128 (2005). A remarkable essay by one of the most prominent former U.S. weapon designers. Based upon the arguments of latent proliferation and the threat of radiological terrorism, the author makes the case for abolition of nuclear weapons—but also for a simultaneous global phase-out of nuclear energy. (E)

## C. Missiles and missile defenses

The development of missiles as delivery systems for nuclear weapons in the late 1950s and 1960s was seen as transforming the nature of modern strategy and warfare. A wide variety of ballistic missiles have been developed, from short-range battlefield missiles to Intercontinental Ballistic Missiles (ICBMs) having ranges up to 10,000–15,000 km that can be based in silos, on mobile launchers, or on submarines. Ground-launched, sea-launched, and aircraft-launched cruise missiles, which rely on a jet engine rather than a rocket engine for propulsion, also have become nuclear-weapons delivery systems. A particular concern about ICBMs has been their very short flight times and their utility for a nuclear first strike (or preemptive attack). This has led in turn to dangerous strategies that rely on keeping missiles on high alert, so they can be launched quickly in case of warning of an attack.

The threat from missiles has led to a persistent search for missile defenses. The arms-control community was able to show in the 1960s that there were simple countermeasures to mid-course defenses against long-range ballistic missiles, which paved the way for the 1973 Anti-Ballistic Missile Treaty. The search for missile defenses was revived in the United States a decade later under President Reagan, as part of the Strategic Defense Initiative (SDI, also "Star Wars" program), which featured orbiting interceptor missiles and lasers. It was again effectively critiqued by arms controllers and shelved. However, in December 2001, the United States announced its withdrawal from the ABM Treaty and began to deploy a national missile defense system putatively to protect against possible future long-range missile attacks from Iran and North Korea. This has created considerable concern among Chinese policy makers, who see the U.S. efforts as threatening the relatively small number of Chinese missiles able to reach the United States. The threat of shorter-range missiles that would threaten U.S. expeditionary forces fighting overseas has also led to the development of theater missile defenses, which were first deployed in Western Europe and which are now being exported to other allies. These developments pose continuing challenges to the arms-control community.

### *Ballistic Missiles*

**73.** **Rocket Propulsion Elements: An Introduction to the Engineering of Rockets**, G. P. Sutton and O. Biblarz, 7th ed. (Wiley-Interscience, New York, 2000). This is the classic reference for understanding propulsion systems using both liquid and solid fuels. (I, A)

**74.** "Free flight of a ballistic missile," A. D. Wheelon, ARS J. **29**(12), 915–926 (1959). This is the classic paper that describes the motion of an object under the influence of gravity for a nonrotating, spherical earth. The second part of the paper includes corrections to take into account the earth's rotation, oblateness, and other effects. (A)

**75.** **Dynamics of Atmospheric Reentry**, F. J. Regan and S. M. Anandakrishnan (American Institute of Aeronautics and Astronautics, Washington, DC, 1993). A very useful guide for understanding the physics of reentry through the atmosphere. The first half of the text deals with basic ideas of atmospheric models, the gravitational field, and reentry mechanics. The second half covers more specific topics related to the reentry of missile warheads. (A)

**76.** **Russian Strategic Nuclear Forces**, edited by P. Podvig (MIT, Cambridge, MA, 2004). While focused on nuclear forces, this book has a lot of good information on Russian missiles and their development. (A)

**77.** **International Reference Guide to Space Launch Systems**, S. J. Isakowitz, J. B. Hopkins, and J. P. Hopkins, Jr., 4th Edition (American Institute of Aeronautics and Astronautics, Restin, VA, 2004). This book gives technical data and development histories of current launch systems. This is useful to get a feel for the technical parameters of long-range missiles, especially since many of these launchers had their origins in ballistic missiles. The data on the missiles must be used with caution and checked for internal consistency, especially on foreign launchers. (A)

**78.** "Long-Range Nuclear Cruise Missiles and Stability," G. N. Lewis and T. A. Postol, Sci. Global Securi., **3**(1-2), 49–99 (1992). This paper presents a technical description of cruise missiles and an analysis of various methods of detecting them. (A)

**79.** "Cruise Control," D. Gormley, Bull. At. Sci. **62**(2), 26–33 (2006). A warning about the proliferation of cruise-missiles programs and the need for arms-control agreements that would restrict them. (E)

**80.** "GUI_Missile_Flyout: A General Program for Simulating Ballistic Missiles," G. Forden (MIT, Cambridge, MA, 2006). Software that simulates the flight of single or multistage ballistic missiles over the round and rotating Earth. Windows version available at ⟨web.mit.edu/stgs⟩. (A)

### *Dealerting*

**81.** **Zero Global Alert for Nuclear Forces**, B. G. Blair (Brookings Institution, Washington, DC, 1995). This monograph evaluates the safety consequences of the high alert status of current U.S. and Russian nuclear-force deployments and the dangers of accidental or authorized launch. It has many useful details of nuclear deployments and operations and makes the case for taking nuclear weapons off alert. (A)

**82.** "Taking Nuclear Weapons off Hair-Trigger Alert," B. G. Blair, H. A. Feiveson, and F. von Hippel, Sci. Am. **277**(5), 74–81 (1997). A vivid description of the problems with the still-current U.S. and Russian practice of keeping nuclear weapons on alert and technical options for ending it. (I)

### *Missile Defenses*

**83.** "Anti-ballistic-missile systems," R. Garwin and H. Bethe, Sci. Am.

**218**(3), 21–31 (1968). The classic early paper discussing technical issues related to ballistic-missile defense and countermeasures. (E)

**84.** "Space-based Ballistic-Missile Defense," H. A. Bethe, R. L. Garwin, K. Gottfried, and H. W. Kendall, Sci. Am. **251**(4), 39–49 (1984). A technical critique of the "Star Wars" ballistic-missile defense program proposed by the Reagan administration (E).

**85.** **SDI for Europe? Technical Aspects of Anti-Tactical Ballistic Missile Defenses**, J. Altmann, PRIF Research Report 3 (PRIF, Frankfurt am Main, 1988). This report presents a technical study of missile defenses intended to intercept short and intermediate-range ballistic missiles. (A)

**86.** "Why National Missile Defense Won't Work," G. N. Lewis, T. A. Postol, and J. Pike, Sci. Am. **281**(2), 36–41 (1999). (E)

**87.** **Countermeasures: A Technical Evaluation of the Operational Effectiveness of the Planned US National Missile Defense System**, A. M. Sessler *et al.* (Union of Concerned Scientists and MIT Security Studies Program, Cambridge, MA, 2000). This study, written for a general audience with technical appendices, discusses the operation of hit-to-kill missile defenses and how countermeasures can interfere with the operation of such a system. It then looks in detail at three specific countermeasures that could be built by a country that had the technical capability to build a long-range missile. (E, I)

**88.** **Technical Realities: An Analysis of the 2004 Deployment of a U.S. National Missile Defense System**, L. Gronlund, D. C. Wright, G. N. Lewis, and P. E. Coyle III (Union of Concerned Scientists, Cambridge, MA, 2004). This report gives an analysis of the U.S. ground-based ballistic-missile defense system after the first eight intercept tests, when the system was supposed to be ready for deployment. (A)

## D. Arms control verification

The hostility between the superpowers during the Cold War, the great destructive power of nuclear weapons, and the relatively closed character of the Soviet system led to concern about the question of verification of any agreement. Progress on a number of arms-control treaties was stalled for many years because of a perceived lack of adequate verification. Demonstrating that a treaty would be verifiable became an important arms-control challenge. The superpowers developed sophisticated capacities for surveillance, known as national technical means, but also managed to agree on systems of inspections. There are particularly important technical tradeoffs posed by the transparency required by inspection systems and the need felt by participating states to keep secret information about the design, numbers, and capabilities of nuclear-weapons and delivery systems.

The most wide-ranging system of international nuclear monitoring covers the production of fissile materials and is associated with the Nuclear Nonproliferation Treaty (NPT). Managed by the International Atomic Energy Agency (IAEA), it seeks to provide assurance that civilian nuclear facilities and materials are not being used for weapons purposes. It is likely to play an important role in any verification of a Fissile Material Cutoff Treaty.

**89.** **Reversing the Arms Race**, edited by F. von Hippel and R. Z. Sagdeev (Gordon and Breach Science, New York, 1990). This volume explores some of the technical issues associated with achieving and verifying deep reductions in nuclear arsenals. It is based on articles originally published in *Science & Global Security.* Chapters include weapons models and radiation signatures and the detection and verified elimination of nuclear warheads. The former is also of interest today because the possibility of detecting nuclear-explosive materials and devices in transit is an important part of the debate over how best to prevent nuclear terrorism. (A)

**90.** **Arms Control Verification: The Technologies that Make it Possible**, K. Tsipis, D. Hafemeister, and P. Janeway (Pergamon-Brassey's, New York, 1986). A comprehensive introduction to the technologies used in arms-control verification, with some useful technical details. It contains a useful discussion of how politics and technology interact in the area of verification. (I, A)

**91.** **Nuclear Safeguards and the IAEA**, Office of Technology Assessment, OTA-ISS-615 (U.S. Government Printing Office, Washington, DC, 1995). An introduction to the International Atomic Energy Agency system and procedures for safeguarding nuclear facilities and materials under the Nuclear Non-Proliferation Treaty. (I)

**92.** **Environmental Monitoring for Nuclear Safeguards**, Office of Technology Assessment, OTA-BP-ISS-168 (U.S. Government Printing Office, Washington, DC, 1995). This report describes the emissions that can be expected from nuclear-weapons facilities, in particular from processes to produce fissile materials, the techniques for detecting them, and technologies that could improve the effectiveness of such environmental monitoring. (I)

**93.** **Commercial Satellite Imagery. A Tactic in Nuclear Weapon Deterrence**, B. Jasani and G. Stein (Springer, London, 2002). An assessment of the potential role of commercial satellites for the strengthening of IAEA safeguards, including a review of capabilities and analysis techniques, partly illustrated with case studies. The book includes a useful discussion of the legal issues of the method. (A)

**94.** "Verification of the Shutdown or Converted Status of Excess Warhead Production Capacity: Technology Options and Policy Issues," O. Bukharin and J. Doyle, Sci. Global Securi., **10**(2), 103–124 (2002). Complements the literature on using new technologies for safeguards purposes only. Measures that are explored in this article to support arms control agreements include facility declarations, satellite imagery, inspections, and remote monitoring. (A)

**95.** "Nuclear Archaeology: Verifying Declarations of Fissile-Material Production," S. Fetter, Sci. Global Securi., **3**(3-4), 237–259 (1993). An important paper laying out some ideas of how to verify claims about the production of fissile materials, with relevance both for nuclear disarmament and proliferation. (A)

**96.** **Monitoring Nuclear Weapons and Nuclear-Explosive Materials: An Assessment of Methods and Capabilities**, National Academy of Sciences (National Academy, Washington, DC, 2005). This report describes the procedures and technical means that are currently available to verify declarations of nuclear weapons and fissile materials, as well as means that might detect undeclared stocks and production activities. (A)

**97.** "Eliminating Nuclear Warheads," F. von Hippel, M. Miller, H. A. Feiveson, A. Diakov, and F. Berkhout, Sci. Am. **269**(2), 45–49 (1993). A useful overview of the technical problems and options associated with eliminating nuclear warheads and disposing of the fissile materials they contain. (I)

**98.** **Transparency in Nuclear Warheads and Materials: The Political and Technical Dimensions**, edited by N. Zarimpas (Oxford U. P., New York, 2003). This volume explores the perspectives of the United States, Russia, the U.K., France, and China on increasing transparency about their nuclear weapons and fissile-material stocks, and the different means and procedures that are being used and have been proposed to help create a verification regime for warheads and materials that can contribute to deeper and irreversible nuclear reductions. (A)

## E. Disarmament

The first U.N. General Assembly Resolution (Resolution 1.1, 24 January 1946) called for "the elimination from national armaments of atomic weapons and of all other major weapons adaptable to mass destruction." The goals of nuclear arms control and nonproliferation were formally linked in the 1970 Nuclear Non-proliferation Treaty (NPT). The United States, Russia, Britain, France, and China are all parties and required by the treaty "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament." Nuclear arms control is now widely seen as an incremental approach involving negotiated limits and reductions on nuclear weapons and delivery vehicles that seeks to eventually achieve the prohibition and elimination of nuclear weapons. Both chemical and biological weapons have already been prohibited by international conventions.


**99.** **A Report on the International Control of Atomic Energy (Acheson-Lilienthal Report)**, prepared for the Secretary of State's Committee on Atomic Energy (U. S. Government Printing Office, Washington, DC, 1946). The first official U.S. effort to lay out the problems created by the creation of nuclear weapons and options to resolve them through international agreement. The principal authors included J. Robert Oppenheimer. (E, I)

**100.** **Strategy and Arms Control**, T. C. Schelling and M. H. Halperin (The Twentieth Century Fund, New York, 1961). The classic argument for arms control as a way to meet the common interest among states to reduce the risk and consequences of war. It still serves as a useful guide for thinking about proposals for arms control. (A)

**101.** **The United States and Arms Control: The Challenge of Leadership**, A. S. Krass (Praeger, Westport, 1997). A detailed examination of U.S. efforts at implementing arms-control agreements, including on nuclear weapons, with a focus on the bureaucratic structures, and the costs and benefits of verification. (A)

**102.** **The Abolition**, J. Schell (Knopf, New York, 1984). An important and accessible statement of the case for the elimination of nuclear weapons, and the feasibility of a subsequent transitional period during which countries retain the ability to build or rebuild nuclear weapons buttressed by international inspections. (I)

**103.** **The Struggle Against the Bomb**, L. Wittner (Stanford U. P., Stanford, 1993, 1997, 2003). This three-volume history of the international movement against nuclear weapons since 1945 is a milestone. It provides an invaluable perspective on the larger political context and struggles within which arms-control initiatives have occurred, been frustrated, and succeeded. The volumes cover 1945–1953, 1954–1970, and 1971–2002, respectively. (E, I)

**104.** **The Future of US Nuclear Weapons Policy** (National Academy, Washington, DC, 1997). This report described the state of U.S. and Russian nuclear forces and policies, and made a case for reduction in warhead numbers from 10,000 each to 1000 each and then to a few hundred each. It considers the conditions under which a global prohibition on the possession of nuclear weapons might become possible and the means to achieve this goal. (I)

**105.** **The Nuclear Turning Point: A Blueprint for Deep Cuts and De-Alerting of Nuclear Weapons**, edited by H. A. Feiveson (Brookings Institution, Washington, DC, 1999). A detailed set of technical and policy proposals for next steps in nuclear arms control that aim to reduce arsenals to a few hundred mostly deactivated weapons. It offers a useful research agenda. (A)

**106.** "The Challenge of Nuclear Weapons," S. D. Drell, Phys. Today **60**(6), 54–59 (2007). This article by a veteran arms-control scientist makes the case for embracing the vision of the elimination of nuclear weapons discussed by Presidents Reagan and Gorbachev at the 1986 Reykjavik Summit. It outlines a series of steps toward this goal developed during a Stanford University conference marking the 20th anniversary of the Summit and endorsed by several former Secretaries of State, Secretaries of Defense, policy makers, and scholars. (E)


## F. The role of scientists in the arms-control process


**107.** **Report to the Secretary of War, by the Committee on Political and Social Problems, Manhattan Project "Metallurgical Laboratory," University of Chicago, June 11, 1945 (The Franck Report).** This pioneering and prescient effort by scientists to assess the problems for international security created by the invention of nuclear weapons foresaw the risks of proliferation and arms races, and made a case for arms control and international agreement on nuclear disarmament. (E)

**108.** **The Advisors: Oppenheimer, Teller and the Superbomb**, H. F. York (Stanford U. P., Stanford, 1976). The text and an analysis of the long-classified 1949 U.S. Atomic Energy Commission's General Advisory Council's report arguing against the development of thermonuclear weapons. It shows the hopes for and limits on scientific input into the policy-making process on national security in the atomic age. (I)

**109.** **American Scientists and Nuclear Weapons Policy**, R. Gilpin (Princeton U. P., Princeton, 1962). An early study by a political scientist of the growing role of physicists in shaping U.S. nuclear-weapons policy and the advent of arms control. It is particularly important for its reflections on the deep differences within the scientific community on nuclear-weapons policy and how this affects arms control. (A)

**110.** **Physics and Nuclear Arms Today**, edited by D. Hafemeister (American Institute of Physics, New York, 1991). Readings from *Physics Today*, originally published between 1976 and 1989. Besides articles focused on the technical dimensions of nuclear arms control, this volume combines contemporary opinion pieces by eminent American physicists on important arms control issues, often in a pro and contra format. (E, I)

**111.** "Physicists in Politics," K. Gottfried, Phys. Today **52**(3), 42–48 (1999). An engaging review essay looking back at the role of physicists in public affairs, especially arms control and international-security affairs over the past 60 years. (E, I)

**112.** "Physics and U.S. National Security," S. D. Drell, Rev. Mod. Phys. **71**(2), 460–470 (1999). A first-hand review of some key areas in which physics has been applied to national security, with relevance to arms control, including the development of satellite imaging, the problems with antiballistic-missile systems, and assuring nuclear-weapons reliability under a test ban. (I)

**113.** **Advice and Dissent: Scientists in the Political Arena**, J. Primack and F. von Hippel (Basic Books, New York, 1974). An important study of the role of scientists as technical experts in modern American policy making, including arms control. (I, A)

**114.** **Citizen Scientist**, F. von Hippel (Simon & Schuster, New York, 1991). A collection of essays on public-interest science spanning 20 years by a leading arms-control physicist, including chapters on the role of scientists, arms races, fissile materials, nuclear-weapons testing, and the effects of nuclear war. (I, A)

**115.** **Making Weapons, Talking Peace: A Physicist's Odyssey from Hiroshima to Geneva**, H. F. York (Basic Books, New York, 1987). An insightful memoir spanning almost 40 years as a scientist involved in nuclear-weapons issues, from working in the Manhattan Project to serving as chief U.S. negotiator at nuclear-test ban treaty talks. It describes the complex bureaucratic politics that shape the U.S. arms-control process. (I)

**116.** **Unarmed Forces: The Transnational Movement to End the Cold War**, M. Evangelista (Cornell U. P., Ithaca, NY, 1999). This book documents the key role played by U.S. and Soviet scientists in providing ideas and information that helped halt or slow the superpowers' arms race at key moments. There are chapters on the effort to stop nuclear-weapons testing and agree on a test ban, prevent the deployment of antiballistic-missile systems, and cut the conventional forces confronting each other in central Europe. (A)


## V. WEBSITES AND BLOGS

There are many government and nongovernment websites and a small number of blogs on nuclear weapons, arms control, and nonproliferation. However, the past few years have seen a return to greater secrecy by government about nuclear information after a period of unprecedented openness in the 1990s, and a great deal of information is no longer as easily available online.

The list below contains websites of independent arms-control groups and international organizations working in the area. It does not include a guide to government departments or national laboratories working on nuclear-weapon issues. We also include a few blogs that have emerged as important resources for the arms-control community.

Arms Control Association, Arms Control Today: <www.armscontrol.org>

Atomic Archive: <www.atomicarchive.com>

Bulletin of the Atomic Scientists: <www.thebulletin.org>

Carnegie Endowment for Peace Nonproliferation Program: <www.carnegieendowment.org/npp>

Digital Library for Nuclear Issues: <alsos.wlu.edu>

Disarmament Diplomacy: <www.acronym.org.uk>

Federation of American Scientists: <www.fas.org>

Global Security: <www.globalsecurity.org>

Institute for Science and International Security: <www.isis-online.org>

International Atomic Energy Agency: <www.iaea.org>

International Panel on Fissile Materials: <www.fissilematerials.org>

Los Alamos Study Group: <www.lasg.org>

Monterey Institute for International Studies, Center for Nonproliferation Studies: <www.cns.miis.edu>

Natural Resources Defense Council: <www.nrdc.org>

Nuclear Information Project: <www.nukestrat.com>

Nuclear Threat Initiative: <www.nti.org>

Richard Garwin Archive: <www.fas.org/rlg>

Union of Concerned Scientists: <www.ucsusa.org>

United Nations Institute for Disarmament Research: <www.unidir.org>

Verification Research, Training and Information Centre: <www.vertic.org>

Armscontrolwonk: <www.armscontrolwonk.com>

Strategic Security Blog: <www.fas.org/blog/ssp>

Russian Strategic Nuclear Forces: <www.russianforces.org>

Verification Blog: <verificationthoughts.blogspot.com>