RESOURCE LETTER

Resource Letter MP-2: The Manhattan project and related nuclear research

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This Resource Letter is a supplement to my earlier Resource Letter MP-1 and provides further sources on the Manhattan Project and related nuclear research. Books and journal articles are cited for the following topics: General works, technical works, biographical and autobiographical works, foreign wartime programs and allied intelligence, technical papers of historical interest, and postwar policy and technical developments. I also give a list of videos and websites dealing with the Manhattan Project, nuclear weapons, and nuclear issues.
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I. INTRODUCTION

This Resource Letter follows the same format as MP-1 (Ref. 1), with three changes: (i) No listing of journals appears; (ii) Sec. D of MP-1, "The German nuclear program," is now titled "Foreign wartime programs and allied intelligence" to more properly reflect its coverage; and (iii) Sec. F, "Postwar developments," is new. While the definition of the term "postwar" is somewhat elastic, I have, in general, restricted myself to the period between 1945 and the testing of the first fusion weapons. My intent in this section is to list a few postwar publications by some of the principal figures involved with the Manhattan Project along with some synoptic works on the arms race for readers interested in developing an overall picture of the postwar period. Consequently, I give only a very selected list of sources within this area; I do not deal with nuclear weapons programs in countries such as France, China, Israel, India, Pakistan, Iran, and North Korea.

In all sections below, I list books first, followed by journal articles. I list sources within Secs. II A 1 and II A 2 in chronological order of publication from earliest to most recent. Sources in Secs. II B–II F are in no particular order, except that I have made an effort to group works on a given topic.

II. BOOKS AND JOURNAL ARTICLES

The sources cited below are divided into six categories: (A) General works, (B) technical works, (C) biographical and autobiographical works, (D) foreign wartime programs and allied intelligence, (E) technical papers of historical interest, and (F) postwar developments. I omit introductory paragraphs for each section unless there is something particular to comment on beyond what I discussed in Resource Letter MP-1. As was the case with MP-1, many sources might arguably be assigned to a different category.

A. General works

1. Synoptic overviews

1. "Resource Letter MP-1: The Manhattan Project and related nuclear research," B. C. Reed, Am. J. Phys. **73** (9), 805–811 (2005). My first Resource Letter, which I recommend as an entry point into the vast literature on the Project. (E, I, A)

2. **Atom Bombs: The Top Secret Inside Story of Little Boy and Fat Man,** J. Coster-Mullen (J. Coster-Mullen, Waukesha, WI, 2002). This remarkable self-published book contains a trove of photographs, diagrams, and copies of documents, reports, and mission logs pertinent to the design, construction, and deployment of the Little Boy and Fat Man bombs and the Hiroshima and Nagasaki missions. Available from online booksellers. (I)

3. **Remembering the Manhattan Project. Perspectives on the Making of the Atomic Bomb and Its Legacy,** C. C. Kelly, ed. (World Scientific, Singapore, 2004). A collection of papers presented at a symposium held in Washington, D.C., in April 2002 sponsored by the Atomic Heritage Foundation, including some personal reminiscences of individuals who worked on the Project in various capacities. Includes an extensive report prepared by the

Foundation and presented to Congress on a strategy for preserving Manhattan Project sites. (E)

4. **Before the Fallout: From Marie Curie to Hiroshima,** D. Preston (Berkley, New York, 2006). A very readable survey of the development of nuclear physics and the Manhattan Project from the time of Marie Curie through the bombing of Hiroshima; explores the scientific, political, and moral "fallout" of the bombing. Some of the physics is occasionally garbled. (E)
5. **The Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses, and Historians,** C. C. Kelly, ed. (Black Dog and Leventhal Publishers, New York, 2007). An anthology of diverse memoirs and histories of the Manhattan Project varying from less than one to a few pages. As most of these are drawn from other sources, they will be familiar to readers familiar with Project literature, but this work does include excerpts from oral histories than otherwise can be difficult to access. (E)
6. **How to Photograph an Atomic Bomb,** P. Kuran (Visual Concept Entertainment, Hollywood, 2007). The United States detonated over 200 above-ground tests of nuclear weapons before the 1963 Limited Test Ban Treaty. In 1947, a special unit of cinematographers was established to film these tests, eventually producing about 6500 films. This book contains photos from a half-dozen of these tests. The text is superficial and punctuated by occasional egregious errors (such as quoting incorrect dates for the Hiroshima and Nagasaki bombings), but the photographs are stunning. (E)
7. **Nuclear Weapons: What You Need to Know,** J. Bernstein (Cambridge U. P., Cambridge, UK, 2008). This volume summarizes the development of nuclear weapons from the discoveries of Thomson and Rutherford through the North Korean test of 2006. Full of interesting personal anecdotes and sidebar stories. See also Ref. 14. (I)
8. **Hiroshima: The World's Bomb,** A. J. Rotter (Oxford U. P., Oxford, 2008). This book offers a fairly compact synoptic treatment from the work of Rutherford and the Curies through the discovery of fission, the development of atomic bombs, Hiroshima and Nagasaki, and the emergence of the Cold War and proliferation of nuclear weapons. This work is somewhat thin as to the science involved and is occasionally repetitive. (E)
9. **Historic Photos of the Manhattan Project,** T. Joseph (Turner Publishing Co., Nashville, TN, 2009). This "coffee-table" book includes nearly 200 black-and-white photos from various Project venues, many showing ordinary employees at work and recreation, as well as shots of Hiroshima and Nagasaki. See also Ref. 9 of MP-1. (E)
10. **The First War of Physics: The Secret History of the Atom Bomb, 1939–1949,** J. Baggott (Pegasus Books, New York, 2010). The title of this book is overstated in that readers familiar with the Project will not find new information here, but Baggott has produced a popularly accessible single-volume work that covers the ground from the discovery of fission to just after the detonation of the first Soviet nuclear weapon in 1949, with some brief coverage at the end of the development of fusion weapons and Oppenheimer's security hearing. The story is related chronologically, with scientific, military, and diplomatic developments in America, Russia, UK, and Germany described in numerous short sections. Descriptions of Soviet espionage activities as divined from Venona decrypts are woven into the story. (E)

2. General works: Specific topics within the Manhattan Project

11. **Technically Sweet Los Alamos: The Development of a Federally Sponsored Scientific Community,** M. B. Chambers (Ph.D. thesis, University of New Mexico, 1974). In this nearly 400-page unpublished thesis based on examination of Manhattan District and AEC records, Chambers gave a detailed description of the administrative development of Los Alamos. A plethora of issues are examined including land acquisition, labor supply, schools, development, the Town Council, dormitory life, utility supply, housing, voting rights, overlapping federal and state jurisdictional issues, transition to AEC administration, and the formation of Los Alamos County. Chambers's underlying thesis is that only with generous federal funding and advanced technology could Los Alamos have become a permanent community. Available as a pdf document through University Microfilms International at ⟨http://disexpress.umi.com/dxweb⟩. (E)
12. **Inventing Los Alamos: The Growth of an Atomic Community,** J. Hunner (University of Oklahoma Press, Norman, OK, 2004). Hunner examined the growth of Los Alamos from 1943 until 1957 (when the public could begin entering the town without security passes), focusing on social history through the memoirs of families and children, the interplay between families and secrecy, community and laboratory, and "atomic hope and fear" as the town evolved into a "model town of the future." (E)
13. **Shockwave: Countdown to Hiroshima,** S. Walker (HarperCollins, New York, 2005). Moving between sites such as Los Alamos, Tinian Island, Potsdam, Tokyo, Washington, and Moscow, Walker dramatically related events in the 3 weeks between the Trinity test and Hiroshima with particular attention to the mission of the *Enola Gay* and the suffering of the victims of the Hiroshima bombing. The physics in this treatment is erroneous in places, but the story is compelling. (E)
14. **Plutonium: A History of the World's Most Dangerous Element,** J. Bernstein (Joseph Henry Press, Washington, D.C., 2007). Reviews the history of the discovery of fission and plutonium, its bizarre chemical properties, and the crucial, often-overlooked contributions of metallurgists at Los Alamos. (I)
15. **A Guide to Manhattan Project Sites in Manhattan,** C. C. Kelly and R. S. Norris (Atomic Heritage Foundation, Washington, D.C., 2008). This thin booklet gives a tourist's guide to Manhattan Project-related sites in Manhattan itself: Oppenheimer's childhood home, office buildings, warehouses, and Columbia University. See also "Why They Called It the Manhattan Project," W. J. Broad, *The New York Times* **CLVII** (No. 54, 113), October 30, 2007, pp. D1 and D4. (E).
16. **A Guide to Manhattan Project Sites in New Mexico,** C. C. Kelly (Atomic Heritage Foundation, Washington, D.C., 2010). This companion volume to Ref. 15 gives brief descriptions and photographs of the numerous Project-associated sites in New Mexico: The Lamy train station, 109 East Palace Avenue, the La Fonda Hotel, structures at Los Alamos, locations in Santa Fe where

Klaus Fuchs and Harry Gold met, and the Trinity site. Not all locations are accessible to the public, but this may change if a Manhattan Project National Historic Park is established (Ref. 115). (E)

17. Historic American Engineering Record: B Reactor (105-B Building), HAER No. WA-164. One of a number of reports available on the U.S. Department of Energy website pertaining to remediation of the Hanford site, this document describes the design, construction, and operation of the Hanford B-reactor, the first plutonium production reactor to go critical. Illustrated with a number of figures and photographs. Available at ⟨http://www.cfo.doe.gov/me70/history/NPSweb/DOE-RL-2001-16.pdf⟩. (I)

18. "The Oppenheimer Years 1943–1945," compiled by Judith M. Lathrop, *Los Alamos Science*, No. 7, 6–25 (Winter/Spring 1983). This edition of *Los Alamos Science* was published on the occasion of the 40th anniversary of the establishment of the laboratory and includes a number of articles dealing with its evolution during that time. This particular article consists of extracts from memos, minutes of meetings, and letters written between September 1942 and the Trinity test. Topics range from mundane, but necessary details such as room rental rates to issues such as the reorganization of the laboratory to deal with implosion. Includes a copy of the text of Oppenheimer's November 1945 speech upon accepting the Army-Navy Excellence Award for the work of the laboratory. (E)

19. "Opening the black box at Bradbury Science Museum, Los Alamos," R. W. Seidel, Phys. Perspect. **2** (2), 211–216 (2000). The Bradbury Science Museum at Los Alamos is named after the Laboratory's second director, Norris Bradbury, who during the Manhattan Project oversaw the final assembly of the Trinity device. Robert Seidel was the museum's administrator from 1985 to 1990. In this article, he described the history of the museum and its exhibits, which pertain not only to the Manhattan Project but also to current laboratory activities such as stockpile stewardship, modeling and simulation, and environmental research. The Museum's website is ⟨http://www.lanl.gov/museum⟩. (E)

20. "The development of nuclear reactor theory in the Montreal Laboratory of the National Research Council of Canada (Division of Atomic Energy) 1943–1946," M. M. R. Williams, Prog. Nucl. Energy **36** (3), 239–322 (2000). The Canadian contribution to the Manhattan Project is often overlooked. In 1943, the British suggested that a joint British–Canadian laboratory for research leading to construction of a pilot plant for producing Pu be established; this was set up in Montreal. This paper reviews the contributions to this effort by the nuclear theory group, which included such notable individuals as Pierre Auger, Hans von Halban, Carson Mark, Robert Marshak, George Placzek (who headed the Theoretical Division), and George Volkoff. This group was particularly active in areas such as criticality and transport theory. One of the results of this work was the Zero-Energy Experimental Pile (ZEEP), a heavy-water-moderated reactor that was the first reactor to go critical outside of the United States (September 5, 1945). This paper gives annotated abstracts of 249 reports produced by this group as well as short biographies of some of the members and details on some early British reports by Peierls, Fuchs, and Dirac. (E).

21. "'In no sense vital and actually not even important'? Reality and perception of Britain's contribution to the development of nuclear weapons," S. Lee, Contemporary British History **20** (2), 159–185 (2006). The quotation in the title of this paper comes from an anonymous source in the Manhattan Projects' official history, as quoted by Szasz in MP-1 (Ref. 15). This paper analyzes the evolution of the perception that the Manhattan Project was an almost exclusively American success story, with British contributions in particular being insignificant despite the initiating effects of the Frisch–Peierls memorandum and the MAUD report. Lee examined the interplay between the scientific and the political communities as the project evolved, the evolution of changing American and British influence as reflected in the Quebec and Hyde Park agreements, the contributions of the British Mission, and the effect of the postwar McMahon Act in stimulating the British to pursue their own nuclear weapons' program. She concluded that without the participation of the British, nuclear weapons would likely not have been operational in August 1945. (E)

22. "Patenting the bomb: Nuclear weapons, intellectual property, and technological control," A. Wellerstein, Isis **99** (1), 57–87 (2008). This paper examines how Vannevar Bush used the OSRD to attempt to acquire a monopoly on the patent rights for inventions used in the production of nuclear weapons and nuclear energy as a means of maintaining secrecy; a fascinating examination of a little-known aspect of the Project. (E)

23. "Centrifugation during the Manhattan Project," B. C. Reed, Phys. Perspect. **11** (4), 426–441 (2009). Consideration of centrifugation as a means of uranium enrichment during the Project was considerably more involved than is commonly appreciated and involved an extensive program of contracts, pilot plants, and proposals for production plants. This paper explores the history of this aspect of the project and how it came to be discontinued in early 1944. (E)

24. "Bullion to B-fields: The silver program of the Manhattan Project," B. C. Reed, Michigan Academician **38**, 205–212 (2009). Over 14,000 tons of silver were borrowed from the U.S. Treasury to make magnet coils for the "calutron" electromagnetic isotope separators at Oak Ridge. This paper relates the history of this substory of the Project. (E)

25. "The Bonebrake Theological Seminary: Top-secret Manhattan Project site," K. R. Sopka and E. M. Sopka, Phys. Perspect. **12** (3), 338–349 (2010). During World War II, the Monsanto Chemical Co. established a facility in a former seminary just outside Dayton, Ohio, to develop the polonium-based initiator units used in *Fat Man* and *Little Boy*. This paper, written by the wife and daughter of chemist John J. Sopka, who worked at the facility from late 1943 to August 1945, relates some of the story of how the polonium was produced and isolated. See also Ref. 129. (E)

26. "Liquid thermal diffusion during the Manhattan Project," B. C. Reed, Phys. Perspect. (in press). Within a few months in mid-late 1944, the S-50 plant at Oak Ridge was hastily constructed to perform the first stage of uranium enrichment based on a thermal diffusion process that had been developed by Philip Abelson under the auspices of the Naval Research Laboratory. This paper explores the development and operation of this facility and some of the associated political wrangling. (E)

B. Technical and historical works

27. **Selected Scientific Papers of Sir Rudolf Peierls with Commentary,** R. H. Dalitz and Sir R. Peierls, eds. (World Scientific, Singapore, 2007). Contains a compendium and reproductions of selected reports written by Peierls for the British “Directorate of Tube Alloys” between 1940 and 1945. The vast majority concern analysis of diffusion plants, but topics such as the physics of fast neutrons and critical mass calculations also appear. See also Lee’s volume of Peierls’ personal correspondence, Ref. 57. (A)

28. **The Physics of the Manhattan Project,** B.C. Reed (Springer, Heidelberg, 2010). I recommend this undergraduate-level treatment of the physics of critical mass, estimating bomb efficiency and yield, uranium enrichment, plutonium synthesis, and complicating factors in bomb design such as the danger of predetonation induced by spontaneous fissions. A companion website ⟨www.manhattanphysics.com⟩ hosts spreadsheets that users can download to run calculations for themselves. (I)

29. “On the classical model of nuclear fission,” M. S. Plesset, Am. J. Phys. **9** (1), 1–10 (1941). This paper, apparently overlooked by generations of textbook authors, fills in the mathematical details of the Bohr–Wheeler calculation of the surface and Coulomb energies of the liquid-drop model at a senior-undergraduate level. (A)

30. “The Bohr–Wheeler spontaneous fission limit: An undergraduate-level derivation,” B. C. Reed, Eur. J. Phys. **30**, 763–770 (2009). Like Plesset’s paper (Ref. 29), this article presents an undergraduate-level treatment of the liquid-drop model but with somewhat clearer notation than employed by Plesset. A supporting document detailing every step of the algebra is available at the same website as given in Ref. 28. (A)

31. “Arthur Compton’s 1941 report on explosive fission of U-235: A look at the physics,” B. C. Reed, Am. J. Phys. **75** (12), 1065–1072 (2007). Between May and November 1941, Arthur Compton prepared three reports for the National Academy of Sciences on prospects for utilizing atomic energy. The first two dealt primarily with the prospects for obtaining a chain reaction, while the third analyzed the conditions necessary for a fission weapon utilizing ^{235}U. This paper examines this physics in Compton’s third report, in particular, his analysis of the critical mass and expected efficiency of such a weapon. (I)

32. “A brief primer on tamped fission-bomb cores,” B. C. Reed, Am. J. Phys. **77** (8), 730–733 (2009). This paper extends the analysis of Ref. 31 to incorporate the effect of a surrounding tamper on the critical mass, yield, and efficiency of a fission weapon. (I)

33. “Student-level numerical simulation of conditions inside an exploding fission-bomb core,” B. C. Reed, Natural Science **2** (3), 139–144 (2010). This paper complements Refs. 31 and 32 by providing a spreadsheet-based program for tracking conditions of expansion, pressure, fission rate, and energy release inside a detonating bomb core. (I)

34. “Predetonation probability of a fission-bomb core,” B. C. Reed, Am. J. Phys. **78** (8), 804–808 (2010). The development of the Fat Man implosion weapon was necessitated by the high spontaneous fission rate of Pu-240, an inevitable by-product of producing Pu-239 in the Hanford piles. This paper presents a student-level analysis of estimating the predetonation probability for a core contaminated with a given percentage of spontaneously fissioning material. (I)

35. “The uranium bomb, the Calutron, and the space-charge problem,” W. E. Parkins, Phys. Today **58** (5), 45–51 (2005). The author, who participated in the development of Ernest Lawrence’s calutrons, described the difficulties encountered in developing electromagnetic separation of uranium isotopes. (I)

36. “Understanding plutonium production in nuclear reactors,” B. C. Reed, Phys. Teach. **43**, 222–224 (2005). Undergraduate-level treatment of how knowledge of reaction cross sections and the power output of a reactor can be used to estimate its rate of plutonium production. (I)

37. “Studying the effects of nuclear weapons using a slide-rule computer,” A. Shastri, Phys. Teach. **45**, 559–563 (2007). Describes the construction and use of a downloadable slide rule that allows one to quickly determine the magnitudes of blast, thermal, and ionizing radiation effects resulting from the detonation of a nuclear device. (I)

38. “Experiments with the Dragon machine,” R.E. Malenfant. This Los Alamos Report (No. LA-14241-H) issued in August 2005 is a reproduction of a September 1945 report by Otto Robert Frisch, describing the construction and operation of the “Dragon” machine, in which a slug of fissile material was allowed to fall and pass through a nearly critical assembly of similar material, thus creating for about 1/100 of a second the conditions for a prompt neutron chain reaction. Available online at ⟨www.osti.gov/bridge/servlets/purl/876514-I1Txj9/⟩. (A)

39. “The nuclear explosive yields at Hiroshima and Nagasaki,” W. G. Penney, D. E. J. Samuels, and G. C. Scorgie, Philos. Trans. R. Soc. London, Ser. A **266** (1177), 357–424 (1970). Lord Penney was a member of the first damage-assessment team to visit Hiroshima and Nagasaki after the Japanese surrender. This paper details exhaustive theoretical and experimental analyses of blast, drag, distortion, and crush data to derive yields of 12 ± 1 ktons (Hiroshima) and 22 ± 2 ktons (Nagasaki) for the explosions. (A)

40. “The search for transuranium elements and the discovery of nuclear fission,” R. L. Sime, Phys. Perspect. **2** (1), 48–62 (2000). Sime described the experiments that led to the discovery of fission and how the assumptions and techniques that both physicists and chemists brought to the work biased experiments and the interpretation of their results against discovering fission in favor of presuming that transuranic elements were being created. The author characterized the misguided search for transuranic elements as an illustration of “illogicality in the progress of science.” See also Sime’s biography of Lise Meitner (MP-1, Ref. 79). (I)

41. “An inconvenient history: The nuclear-fission display in the Deutsches Museum,” R. L. Sime, Phys. Perspect. **12**

(2), 190–218 (2010). A longstanding attraction at the Deutsches Museum in Munich has been a display of apparatus associated with the discovery of nuclear fission, notably Otto Hahn's "worktable." Sime related how for many years the display mentioned Fritz Strassmann only peripherally and Lise Meitner, who designed and assembled the apparatus, not at all, and traced the recent transformation of the exhibit into one that more accurately represents the actual history of the discovery of fission. Particularly interesting is how after the war Hahn himself erased Meitner's contributions to the work to the point of suggesting that physics had only impeded the discovery. See also Refs. 66 and 67. (E)

42. "Chadwick and the discovery of the neutron," B. C. Reed, SPS Observer **39** (1), 1–4 (2007). Available online at ⟨www.spsobserver.org/2007/observer_spring.pdf⟩. Undergraduate-level analysis of the experiments and calculations leading to Chadwick's 1932 discovery of the neutron. (I)

C. Biographical and autobiographical works

43. Reappraising Oppenheimer: Centennial Studies and Reflections, C. Carson and D. A. Hollinger, ed. (Office for History of Science and Technology, University of California, Berkeley, CA, 2005). Essays examining Oppenheimer's life, personality, and work based on papers presented at a conference in Berkeley in 2004 to mark the centennial of his birth. The majority of the contributions are not oriented toward Oppenheimer's physics, but one by David Cassidy does examine his transition from theoretical to applied bomb physics, while another by Karl Hufbauer gives an accessible study of the theoretical discovery of black holes by Oppenheimer and his students in the 1930s. (E)

44. The Ruin of J. Robert Oppenheimer and the Birth of the Modern Arms Race, P. J. McMillan (Viking, New York, 2005). Based on interviews and documentary evidence, McMillan examined technical, political, and military developments leading to the development of the hydrogen bomb and Oppenheimer's security-clearance hearing of 1954. A chilling account of how a politically motivated persecution can destroy even a famous public figure. (E)

45. Oppenheimer and the Manhattan Project: Insights into J. Robert Oppenheimer, "Father of the Atomic Bomb," C. C. Kelly, ed. (World Scientific, Singapore, 2006). At a symposium sponsored by the Atomic Heritage Foundation and held at Los Alamos in June 2004, historians, scientists, government officials, and some of Oppenheimer's former students presented papers on his life and work; their talks are reproduced in this volume. (E)

46. J. Robert Oppenheimer: A Life, A. Pais, with supplemental material by R. P. Crease (Oxford U. P., New York, 2006). Pais completed about three-quarters of this work before his death in August 2000; it was completed by his widow and Robert Crease. Pais was a faculty member at the Institute for Advanced Study and knew Oppenheimer from 1946 until his death in 1967. Written in an appealing style that combines physics and personal reminiscences, the emphasis here is not so much on Oppenheimer's Los Alamos years, but rather on his contributions to the growth of American theoretical physics, his directorship of the Institute for Advanced Studies, as a leader of conferences, and his service on numerous government committees and task forces. Pais is unsparing in his opinion that Oppenheimer's arrogance was a large factor in his downfall. (E)

47. J. Robert Oppenheimer, the Cold War, and the Atomic West, J. Hunner (University of Oklahoma Press, Norman, OK, 2009). This compact volume is one of a series of "Oklahoma Western Biographies" that relate the life stories of significant westerners and how their lives illuminate a topic in the history and culture of the American West. Hunner described Oppenheimer's life and his role in developing the "scientific west" at Berkeley, Caltech, and Los Alamos, arguing that World War II transformed the West in the 20th century much as the gold rush had in the 19th. This work contains no detailed list of sources, but rather a bibliographic essay of major works on Oppenheimer and the Manhattan Project. Recommended for a reader looking for a no-frills treatment of Oppenheimer's life and work, but does contain occasional factual errors (E).

48. A Life in Twilight: The Final Years of J. Robert Oppenheimer, M. Wolverton (St. Martin's Press, New York, 2008). Chronicles Oppenheimer's life and career from the time of his security hearing in early 1954 to his death in 1967. Each chapter is bookended at its beginning with a reproduction of a document from FBI files detailing the absurd level of monitoring that Oppenheimer was subject to, and at its end by brief descriptions of key points of the security hearing. Particularly interesting is Wolverton's description of the Senate grilling that Oppenheimer's nemesis Lewis Strauss was subject to (and which brought his public career to an end) in 1959 when President Eisenhower nominated him to be the Secretary of Commerce. (E)

49. J. Robert Oppenheimer and the American Century, D. C. Cassidy (Johns Hopkins U. P., Baltimore, 2009). This is a new soft cover edition of Ref. 63 of MP-1, which has gone out of print. One of the few Oppenheimer biographies that integrate Oppenheimer and his prewar physics into the growth of American physics in the 1920s and 1930s, which set the stage for the Manhattan Project. (E)

50. Beyond Uncertainty: Heisenberg, Quantum Physics, and the Bomb, D. C. Cassidy (Bellevue Literary Press, New York, 2009). This is a significantly revised and updated version of the author's earlier *Uncertainty: The Life and Science of Werner Heisenberg* (MP-1, Ref. 78), which was published before the release of the Farm Hall transcripts. Chapters 22–29 deal with Heisenberg's role in the German nuclear effort, his meeting with Bohr in September 1941, and the "explanations" offered by the interned German scientists at Farm Hall. Cassidy developed the viewpoint that under motivations of patriotism and a sense of personal responsibility for the preservation of German physics, Heisenberg worked with the Nazi regime under the rationalization that he could live and work as a subject of the system but not be a part of it and thus have no responsibility for it. See also the Bohr–Heisenberg letters that were made public in 2002 (MP-1, Ref. 143). (E)

51. Rider of the Pale Horse: A Memoir of Los Alamos and Beyond, M. Hull with A. Bianco (University of New Mexico Press, Albuquerque, 2005). In the Fall of

1944, Hull arrived at Los Alamos as a 21-yr-old SED to cast implosion lenses. In this brief memoir, he recounts the problems encountered and overcome with this process. In contrast to the many works that describe Los Alamos from the perspective of leading physicists, this work describes the dangerous work carried out by many lower-echelon employees. After the war, Hull worked on calculations of bomb phenomenology for the Bikini tests of 1946 and went on to a successful career as a physicist and university administrator. For a story involving Oppenheimer, Groves, and a broken water line alone, this volume is worth its price. (E)

52. Uncle Phil and the Atomic Bomb, J. Abelson and P. H. Abelson (Roberts and Co., Greenwood Village, CO, 2008). Philip Abelson (1913–2004) was involved in the discovery of neptunium, developed the liquid thermal diffusion method of uranium-isotope enrichment employed at Oak Ridge, and, in 1946, developed a proposal for a nuclear-powered submarine based on refitting a German-designed vessel. This volume is based on autobiographical notes that Abelson passed on to his nephew, who annotated them and added some family photographs. (E)

53. Atomic Tragedy: Henry L. Stimson and the Decision to Use the Bomb Against Japan," S. L. Malloy (Cornell U. P., Ithaca, 2008). A biography of Stimson based on his diaries and papers with particular emphasis on the evolution of Stimson's thoughts on the military and diplomatic uses of the atomic bomb and his efforts to avoid a postwar arms race. Contains an interesting analysis of the development of Stimson's 1947 *Harper's* article (Ref. 102). (E)

54. Target Hiroshima: Deak Parsons and the Creation of the Atomic Bomb, A. Christman (Naval Institute Press, Annapolis, MD, 1998). Navy Captain William Parsons headed the Ordnance Division at Los Alamos, was largely responsible for the design of the Little Boy gun bomb, and personally armed that weapon during the Hiroshima mission. This biography reviews Parson's life and career including his work with radar and proximity-fuze programs, his time at Los Alamos, his postwar work in establishing the "Nuclear Navy," and his involvement in operations Crossroads and Sandstone. Parsons participated in all of these and witnessed seven of the first eight nuclear explosions in history. (E)

55. Atomic Fragments: A Daughter's Questions, M. Palevsky (University of California Press, Berkeley, 2000). Palevsky's parents worked at Los Alamos and in their later years expressed misgivings about having helped to create the bombs. After their deaths in the late 1980s, she interviewed a number of leading Manhattan Project scientists including Hans Bethe, Edward Teller, Philip Morrison, and Robert R. Wilson, who were unusually open in sharing memories of their work and thoughts on the results; most believed that they had done the right thing. Palevsky later collected oral histories of individuals associated with the Nevada Test Site; these can be found online at ⟨http://digital.library.unlv.edu/ntsohp/⟩. (E)

56. Los Alamos Experience, P. Fisher (Japan Publications, Inc., Tokyo, 1985). In October 1944, the author and her family moved to Los Alamos, where her husband, a physicist, was recruited to work in Luis Alvarez's group developing detonators for the implosion bomb. Fisher's mother kept over 100 letters that she wrote home during the next two years; this book presents excerpts from the letters and reflections on the experience after a remove of 40 years. One can sense the frustrations of daily life spent in isolation subject to seemingly arbitrary regulations and erratic supplies of food, water, and electricity, frustrations made bearable by the spectacular scenery and development of deep friendships among young families. Her recollections of profoundly mixed feelings upon learning of what her husband had been working on when Hiroshima and Nagasaki were bombed are particularly compelling. (E)

57. Sir Rudolph Peierls: Selected Private and Scientific Correspondence, Vol. 1., S. Lee, ed. (World Scientific, Singapore, 2007). Section 5 of this volume (pp. 689–832), titled "1940-45: War," includes copies of private and professional letters to and from Peierls's wife, family members, and colleagues such as Hans Bethe, Max Born, Klaus Fuchs, Robert Oppenheimer, and Francis Simon. Includes extensive correspondence with Chadwick regarding the British Mission, enrichment methods, fast-neutron physics, and developments at Los Alamos. (I)

58. Neutron Physics for Nuclear Reactors: Unpublished Writings by Enrico Fermi, S. Esposito and O. Pisanti (World Scientific, Singapore, 2010). This lengthy volume describes the basics of the functioning and operation of nuclear reactors as described in unpublished papers by Fermi that have been uncovered by the authors. Includes notes taken by Anthony P. French on the entire course of Fermi's 1946 "Neutron Physics" course at Los Alamos as well as a summary of all of the patents issued to Fermi and his co-workers on the construction, functioning, and operation of several different kinds of reactors. See also Refs. 59–62. (A)

59. "Enrico Fermi's discovery of neutron-induced artificial radioactivity: The recovery of his first laboratory notebook," G. Acocella, F. Guerra, and N. Robotti, Phys. Perspect. **6** (1), 29–41 (2004). This paper describes the authors' discovery of Fermi's laboratory notebook that covers the beginning period of his experiments on neutron-induced radioactivity in March–April 1934. Contrary to popular understanding, his first experiment involved irradiating platinum (for 15 min), but no effect above background was detected. He then moved on to experimenting with aluminum and fluorine, achieving success. (E)

60. "Enrico Fermi's discovery of neutron-induced artificial radioactivity: Neutrons and neutron sources," F. Guerra, M Leone, and N. Robotti, Phys. Perspect. **8** (3), 255–281 (2006). The authors reviewed the history of neutron-bombardment work in Italy and how Fermi had to overcome problems of gamma-ray background, Radon extraction, neutron-energy spectra, and experimental geometry. They argued that the commonly held image of the "continuity" of Fermi's research program in nuclear physics from about 1931 onward is not supported by an examination of his laboratory notebooks and that he turned to neutron-induced radioactivity only after the appearance of his theory of beta decay in late 1933 to early 1934 and the discovery of artificially induced radioactivity by Joliot and Curie. (E)

61. "Enrico Fermi's discovery of neutron-induced artificial radioactivity: The influence of his theory of beta decay,"

F. Guerra and N. Robotti, Phys. Perspect. **11** (4), 379–404 (2009). In this companion paper to Refs. 59 and 60, the authors explored the influence of Fermi's theory of beta decay on the planning of his neutron-bombardment experiments, in particular, on his choice of a Rn–Be neutron source and the choice of elements to be bombarded. The authors assigned the date of March 20, 1934 to the discovery of neutron-induced radioactivity. (E)

62. "Enrico Fermi and the physics and engineering of a nuclear pile: The retrieval of novel documents," S. Esposito and O. Pisanti, arXiv:0803.1145v1. The authors described a number of previously uncovered papers and patents that trace the evolution of the work of Fermi and his collaborators in developing reactors. Gives a complete list (over 300 items) of Fermi's papers. (I)

63. "A conversation with Robert F. Christy—Part I," S. Lippincott, Phys. Perspect. **8** (3), 282–317 (2006); Part II, Phys. Perspect. **8**(4), 408–450 (2006). Christy took his Ph.D. degree with Oppenheimer in 1941 and went to Los Alamos in the spring of 1943 as a member of the Theoretical Division where he was involved with criticality calculations, devised the hollowed-sphere plutonium implosion "Christy core," and witnessed the Trinity test. After the war, he was active in the Association of Los Alamos Scientists (ALAS) and had a famous falling-out with Edward Teller over the latter's testimony during Oppenheimer's security-clearance hearings. This pair of articles reviews Christy's life and work from his childhood forward, including his time as Provost and later Acting President of the California Institute of Technology. (E)

64. "Inventing a climate of opinion: Vannevar Bush and the decision to build the bomb," S. Goldberg, Isis **83** (2), 429–452 (1992). Goldberg challenged the common view that the decision to go forward with a full-scale attempt to build the atomic bomb was a consensual one based on technical studies, arguing instead that the decision was made by Vannevar Bush in April 1941 and that he manipulated the National Academy of Science's Committee on Atomic Fission to yield reports to support this decision. Goldberg supported this contention by a careful examination of correspondence between parties such as Bush, Conant, Briggs, Compton, and NAS President Frank Jewett. (E)

65. "Between autonomy and accommodation: The German Physical Society during the Third Reich," D. Hoffmann, Phys. Perspect. **7** (3), 293–329 (2005). While there is little in this paper concerning fission or the German nuclear program *per se*, it is invaluable for getting a sense of how the venerable German Physical Society (Deutsche Physikalische Gesellschaft, DPG) was affected by and accommodated to the realities of political life under the Nazis; as such it forms an excellent prologue to Refs. 66 and 67. Hoffmann particularly examined how the actions and policies of physicist Carl Ramsauer, who was elected Chairman of the DPG in mid-1940, were directed to forging alliances with the Nazi military-industrial complex. Hoffmann concurred with Sime and Walker that the postwar apologias offered by many German scientists to the effect that they pursued passive resistance to the Nazis while preserving German science do not stand up to close scrutiny. He summarized Ramsauer's actions with the description that "… he became a participant in the great postwar alliance of silence in Germany." A briefer version of this work appeared as MP-1, Ref. 115. (E)

66. "The politics of memory: Otto Hahn and the Third Reich," R. Sime, Phys. Perspect. **8** (1), 3–51 (2006). Sime examined how Hahn helped Jewish friends and colleagues during the Nazi era, but afterwards, despite its being involved with the German nuclear program, portrayed the Kaiser Wilhelm Society during the war as an apolitical, purely scientific organization beleaguered by an oppressive regime while simultaneously compartmentalizing personal thoughts concerning Nazi atrocities. The author summarized Hahn's behavior as a sort of massive act of forgetting the past. (E)

67. "Otto Hahn: Responsibility and repression," M. Walker, Phys. Perspect. **8** (2), 116–163 (2006). Examines what Hahn and others at the Kaiser Wilhelm Institute for Chemistry did during the Third Reich, in particular, their contributions to the German uranium project during World War II. While Walker is critical of postwar efforts by Hahn and others to reinterpret wartime research in support of Nazi goals as disinterested fundamental research, he concluded that Hahn conducted himself well during the Third Reich in comparison to many of his more opportunistic colleagues. (E)

68. "Fritz Lange, Klaus Fuchs, and the remigration of scientists to East Germany," D. Hoffmann, Phys. Perspect. **11** (4), 405–425 (2009). Hoffmann studied the social and political framework in East Germany within which the remigration of scientists to that country occurred following the war, using as one of his main examples the famous Los Alamos spy Klaus Fuchs. After his release from prison in Britain in 1959, Fuchs was flown directly to East Berlin. He subsequently held a number of high-ranking positions in various research institutes, working intensively on reactor development. While he was eventually elected to membership in East Germany's Communist Party Central Committee, his work as an atomic spy was never formally recognized by the Soviet Union. (E)

69. "The life and scientific contributions of Lyman J. Briggs," E. R. Landa and J. R. Nimmo, Soil Sci. Soc. Am. J. **67** (3), 681–693 (2003). As the Director of the National Bureau of Standards, Briggs (1874–1963), a soil physicist, was the senior physical scientist in the government in the Fall of 1939 and was appointed chair of the Uranium Committee. While his role in the project began to wane by mid-1942, his early involvement and contributions are often overlooked or dismissed by historians. This paper reviews Briggs's life and work, which involved areas as diverse as soil physics, negative pressures, and the spins of baseballs. (E)

70. "Charles C. Lauritsen: A reasonable man in an unreasonable world," C. H. Holbrow, Phys. Perspect. **5** (4), 419–472 (2003). During the war, Lauritsen, who was Director of the Kellogg Radiation Laboratory at the California Institute of Technology, served as Vice-Chair of the armaments section of the National Defense Research Council, where he was involved in developing proximity fuses and rockets and served as a consultant at Los Alamos. There, he was involved in producing conventional explosives for the plutonium bomb and in designing and manufacturing dummy bombs used to test bomb ballistics; he witnessed the Trinity test. After the war, he participated in over 40 government panels and study groups

including Project Vista, an enormous 1951 study of ground and tactical air warfare. He opposed development of the hydrogen bomb and in 1954 testified on behalf of Oppenheimer during the latter's security hearing. This article describes in detail the life and work of this widely accomplished physicist. (E)

71. "James Franck: Science and conscience," F. von Hippel, Phys. Today **63** (6), 41–46 (2010). Franck worked on gas research in Germany in World War I and left Germany for America in the mid-1930s in response to Hitler's laws prohibiting civil servants of non-Aryan descent. During World War II, he headed the chemistry division of Arthur Compton's Metallurgical Laboratory and authored the famous June 1945 Franck report that advocated a demonstration shot of the new fission weapons. This brief biography summarizes Franck's life and work. (E)

72. "Neutron counters, plutonium hemispheres, and welder's glasses: Reminiscences of the Manhattan Project," L. W. Seagondollar, Radiations **11** (2), 18–23 (2005). Available online at ⟨www.sigmapisigma.org/radiations/2005/seagondollar_fall05.pdf⟩. Partway through graduate school in 1944, Seagondollar went to Los Alamos where he worked with plutonium hemispheres, was involved in measuring the critical mass of Pu-239, and witnessed (through welder's glasses) the Trinity test. His very readable first-person account of his experiences is based on a talk he gave at the University of North Carolina. (E)

73. "Working (and not working) on weapons," K. Ford, Radiations **11** (1), 5–7 (2005). Available online at ⟨www.sigmapisigma.org/radiations/2005/ken_ford_spring05.pdf⟩. The author worked on hydrogen bomb calculations as a graduate student from 1950 to 1952, and related how he came to be recruited to the project and how his later disillusionment over the Vietnam War led him to publicly announce that he would no longer participate in any further secret or weapons work. He closes with advice to young scientists facing decisions regarding working on such projects. (E)

D. Foreign wartime programs and allied intelligence

I am grateful to Harry Lusting for an extensive exchange concerning the issue of Allied knowledge of German efforts at developing nuclear weapons. Knowledge of this area has grown considerably since the release of the Farm Hall transcripts (MP-1, Sec. D), but much material still remains classified by the British, especially documents dealing with the spying efforts of *Naturwissenschaften* editor Paul Rosbaud. David Irving's 1968 study of Nazi nuclear-research efforts (MP-1, Ref. 100) was published before the release of the transcripts, which he related that the British were reluctant to admit even existed (his p. 306). In her 1964 work on the history of atomic energy in Britain (MP-1, Ref. 14), Margaret Gowing made only a brief mention as to what British Intelligence had found out about German efforts and only a veiled allusion to Farm Hall, not even using the term explicitly (her pp. 367–368). R. V. Jones (Ref. 75 below), who was involved with transferring the detainees to Farm Hall and taping their conversations there, gave an interesting personal account of that event. An important recent source of information on the German project is documents taken from the wartime Kaiser Wilhelm Institute for Physics by the Russians which were returned to the Max Planck Society in 2004 (Refs. 77 and 80).

There is no definitive work on Japanese work on nuclear weapons research during the war, which never progressed very far at all despite persistent myths the Japanese did develop and test an atomic bomb near the end of the war; the sources listed here handily dispel this myth and should be accessible for most readers.

74. **British Intelligence in the Second World War,** F. H. Hinsley, E. E. Thomas, C. F. G. Ransom, R. C. Knight, C. A. G. Simkins, and M. Howard (Her Majesty's Stationary Office, London, 1979–1990). This massive five-volume work is the official source of unclassified information on British intelligence during the war. Volume 2, pp. 122–128, and Vol. 3, Pt. II, pp. 583–592, are the primary references to intelligence regarding German nuclear research efforts. Appendix 29 of Vol. 3, Pt. II (pp. 931–944) reproduces excerpts from a joint Anglo-U.S. report of November 1944 on German nuclear-efforts that went to both the Chancellor of the Exchequer and to General Groves. This report indicates that it was felt that German scientists who appreciated the potential of nuclear energy had continued to do as much work on the subject as possible but that it was "most probable" that no large immediate-term military program was underway. A briefer popular account of British intelligence efforts appears in Jones's book (Ref. 75). (E)

75. **Most Secret War: British Scientific Intelligence 1939–45,** R. V. Jones (Hamish Hamilton, London, 1978). Jones, an Oxford-educated physicist, served as a Scientific Officer on the staff of the Intelligence Service of the Air Ministry and was responsible for coordinating all British scientific intelligence during the war. This compelling book is largely devoted to efforts involving radio navigation, radar, and V-weapons, but Chaps. 35 and 48 are, respectively, devoted to the Norwegian heavy-water situation and nuclear intelligence in general. Especially interesting is Jones's description of meeting Niels Bohr after he had been flown out of Denmark. He also gave what must be one of the first published descriptions of the conversations among the Farm Hall detainees, relating that they were moved to Britain in response to the suggestion of an American general that the best way of dealing with "the nuclear physics problem" in postwar Germany was to shoot all their nuclear physicists! (E)

76. **Collected Works,** W. Heisenberg (Springer-Verlag, Berlin, 1989). This multivolume series was edited by W. Blum, H.-P. Durr, and H. Recehenberg; the German title is "Gesammelte Werke." Pages 363–601 of Series A/Pt. II of this work contains 21 of Heisenberg's papers on the "Uranium project" (many coauthored) prepared between December 1939 and early 1945. (A)

77. **Hitlers Bombe: Die Geheime Geschichte der Deutschen Kernwaffenversuche,** R. Karlsch (Deutsch Verlags-Anstalt, Munich, 2005). This German-language book is controversial for its remarkable assertions that a group of scientists under Kurt Diebner and Walther Gerlach achieved a chain reaction and detonated two hybrid fission/fusion bombs before the end of the war. An English-language summary by Karlsch and Mark Walker appears in Phys. World **18** (6), 15–18 (2005). Karlsch based much of his work on German documents captured by the Russians and returned to the Max Planck

Society in 2004. An English-language review by historian of science Dieter Hoffmann [Nature (London) **436** (7047), 25–26 (2005)] concludes that the bomb assertion is not borne out by the book's content: The reaction rates and pressures of the purported design are too small by at least two orders of magnitude to initiate a fusion reaction, and it is not made clear how the Germans obtained plutonium or enriched uranium. Hoffmann did argue, however, that Karlsch has produced a valuable work in that it brings to light much previously unknown archival material. See also Ref. 80. (I)

78. **Spying on the Nuclear Bear: Anglo-American Intelligence and the Soviet Bomb,** M. S. Goodman (Stanford U. P., Stanford, 2007). This meticulously researched work examines joint U.S.-British efforts to track Soviet bomb development from 1945 to 1958. Goodman included analyses of the sometimes turbulent relationship between U.S. and British intelligence services, the impacts of spy and defector cases, and the technical means used to gather information on tests. (I)

79. **Japan in War and Peace: Selected Essays,** J. W. Downer (New Press, New York, 1993). This book comprises of a number of essays on wartime and postwar Japan. One of them, "NI and F: Japan's Wartime Atomic Bomb Research" (pp. 55–100) summarizes prewar nuclear research in Japan, describes how reminiscences of wartime nuclear research were widely known through popular media outlets in Japan by the 1970s but became appreciated in the west beginning in only the late 1970s, and summarizes the various stages of the Japanese work. Disunity of research priorities, inadequate staffing, limited resources, lack of central coordinating authority, Army/Navy tensions, and a futile search for uranium ores led to the project being "an erratic endeavor and conspicuous failure" carried out on a meaninglessly small scale until a bombing raid in April 1945 destroyed an experimental diffusion column. At one point, Japanese researchers labored for over a year to produce a single small crystal of uranium hexafluoride. (E)

80. "Nuclear weapons and reactor research at the Kaiser Wilhelm Institute for Physics," in *The Kaiser Wilhelm Society during National Socialism*, S. Heim, C. Sachse, and M. Walker, eds. (Cambridge U. P., Cambridge, 2009), pp. 339–369. This article was published after the return from Russia of captured German documents as described in Ref. 77. Walker presented a review of the German uranium program, reminding readers that it was much greater than Heisenberg alone. One of the interesting revelations of the returned documents is that between the summers of 1940 and 1941, Carl Friedrich von Weizsäcker submitted a patent application that emphasized the military importance of reactors and plutonium. With reference to "Hitler's bomb," Walker stated that "It is clear that a group of German scientists tested what they *thought* would be a nuclear weapon" (emphasis added). He characterized Heisenberg's attitude toward the uranium work both during the war and afterward as "a continuity of ambiguous ambivalence." (E)

81. "A neutronics study of the 1945 Haigerloch B-VIII nuclear reactor," G. Grasso, C. Oppici, F. Rocchi, and M. Sumini, Phys. Perspect. **11** (3), 318–335 (2009). The authors used a Los Alamos-produced Monte Carlo based neutron transport code to analyze the performance of Heisenberg's last wartime reactor (February–April 1945), concluding that it could not have achieved criticality. An interesting aspect of this analysis is that the subcriticality was due not to impure graphite but rather to low efficiency of its heavy-water moderator. See also Ref. 103. (A)

82. "Trinity at Dubna," T. Reed and A. Kramish, Phys. Today **49** (11), 30–33 (1996). This paper and that by Friedman *et al.* (Ref. 83) are contained in a special issue of *Phys. Today* devoted to "New Light on Early Soviet Bomb Secrets." Reed and Kramish were two of the six Americans invited to a reunion of early era Soviet bomb workers held at Dubna in May 1996. They discussed the development of the Soviet nuclear program that led to the Joe-1 test of 1949. Their discussion of Soviet use of forced labor and flagrant disregard for health, safety, and environmental concerns make for sobering reading. (E)

83. "Detecting the Soviet bomb: Joe-1 in a rain barrel," H. Friedman, L. B. Lockhart, and I. H. Blifford, Phys. Today **49** (11), 38–41 (1996). The authors described Office of Naval Research and Air Force work on developing methods to detect, collect, and measure airborne radioactive debris from Soviet bomb tests: Balloon-tethered Geiger counters, filter systems on squadrons of B-29 reconnaissance aircraft, and rainwater collection systems. (E)

84. "Japan's secret war? 'Instant' scientific manpower and Japan's World War II Atomic Bomb Project," M. F. Low, Ann. Sci. **47** (4), 347–360 (1990). The author examined the question of whether or not the Japanese had a sufficient number of physicists trained in nuclear physics to mount a credible atomic bomb project, concluding that they did not. An interesting aspect of this paper is its discussion of how various Japanese government efforts to mobilize scientific and technical work between 1940 and 1945 largely stagnated, belying the usual Western concept of a population monolithically devoted to the war effort. Many Japanese physicists who could have contributed to a bomb project (had sufficient supplies of uranium been available) devoted their energy to elementary-particle research during the war; nuclear weapons research was largely an academic exercise. (E)

85. "Hungnam and the Japanese atomic bomb: Recent historiography of a postwar Myth," W. E. Grunden, Intelligence and National Security **13** (2), 32–60 (1998). A persistent myth that Japan developed and tested an atomic bomb near the city of Hungnam (now in North Korea, then a colony of Japan) near the end of the war began with a newspaper article in 1946. Hungnam was the site of very extensive Japanese munitions and chemical industries, but, as Grunden argued, there is no credible evidence that any fissile materials were produced there. (E)

86. "Wartime nuclear weapons research in Germany and Japan," W. E. Grunden, M. Walker, and M. Yamazaki, Osiris **20**(1), 107–130 (2005). This article is one of a number in this issue of Osiris containing papers on science in wartime and presents a very readable "compare and contrast" of the German and Japanese projects. Interest in fission as a potential weapon was expressed by officials of the Japanese Navy as early as 1934, but wartime research was hampered by a lack of centralized authority in resolving competing Army and Navy projects, low priority, and extremely limited resources as a result of the scientists and military personnel conclud-

ing that a bomb could not be made in time to influence the war. The Japanese did experiment with uranium enrichment by thermal diffusion but were hampered by meager supplies of uranium hexafluoride; their Cluisius tube was destroyed in a bombing raid in April 1945. (E)

87. "Nuclear weapons research in Japan during the Second World War," K. Nagase-Reimer, W. E. Grunden, and M. Yamazaki, Historia Scientiarum **14** (3), 201–240 (2005). Summary of Japanese research during the war published in English in a Japanese history-of-science journal. (E)

E. Technical papers of historical interest

88. "Isotopic constitution of uranium," A. J. Dempster, Nature (London) **136**, 180 (1935). In this single-column paper dated July 12, 1935, and published in the August 3 edition of Nature, University of Chicago mass spectroscopist Arthur Dempster reported the discovery of U-235 and estimated its abundance as $<1\%$ of that of U-238 (E)

89. "The isotopic constitution of uranium and the half-lives of the uranium isotopes. I," A. O. Nier, Phys. Rev. **55**, 150–153 (1939). In this paper published soon after the discovery of fission, Nier reported the first mass-spectrographic detection of U^{234} and determined abundance ratios of $U^{238}/U^{235} = 139$ and $U^{238}/U^{234} = 17{,}000$. (I)

90. "Further experiments on fission of separated uranium isotopes," A. O. Nier, E. T. Booth, J. R. Dunning, and A. v. Grosse, Phys. Rev. **57**, 748–748 (1940). In this follow-up paper to Ref. 126 of MP-1, Nier and his Columbia collaborators verified that ^{235}U is responsible for slow-neutron fission and that ^{238}U undergoes fast-fission only. (I)

91. "Fission of the separated isotopes of uranium," K. H. Kingdon, H. C. Pollock, E. T. Booth, and J. R. Dunning, Phys. Rev. **57**, 749–749 (1940). This paper is published on the *Physical Review* page adjacent to Ref. 90; the authors verified that $^{234+235}U$ is responsible for slow-neutron fission and that ^{238}U does not slow-neutron fission. (E)

92. "Spontaneous fission of uranium," G. N. Flerov and K. A. Petrjak, Phys. Rev. **58**, 89 (1940). In this brief letter cabled from Leningrad on June 14, 1940, the authors reported the first observation of spontaneously fissioning uranium and estimated the mean lifetime for that process as $10^{16}–10^{17}$ yr. The currently accepted figure is about 1.2×10^{16} yr. (E)

93. "Physical evidence for the division of heavy nuclei under neutron bombardment," O.R. Frisch, Nature (London) **143**, 276 (1939). Dated January 16, 1939, and published in the February 18 issue of Nature, this paper by Frisch reports the first deliberate experimental production of fission. Using a uranium-lined ionization chamber and a linear amplifier, Frisch detected ionizations characteristic of 100 MeV ion pairs, finding the effect enhanced by a factor of 2 when the neutrons were slowed with paraffin. Upon repeating the experiment with thorium, he found no paraffin effect. (I)

94. "The time involved in the process of nuclear fission," N. Feather, Nature (London) **143**, 597–598 (1939). Dated March 30, 1939, and published on April 8, Feather described an ingenious experiment utilizing the asymmetry of the kinetic energy of fast-neutron fission products to deduce that fission proceeds on a time scale of no more than about 5×10^{-13} s once a compound nucleus has been formed. (I)

F. Postwar developments

I include here postwar statements by Heisenberg and Oppenheimer that should be readily available in many libraries (Refs. 103 and 104). However, these statements represent only the tip of the iceberg of spoken and written comments on nuclear issues in the postwar years by various leaders of the nuclear community. More citations for Oppenheimer can be found in Smith and Weiner's *Robert Oppenheimer: Letters and Recollections* (MP-1, Ref. 60) and in Cassidy's *J. Robert Oppenheimer and the American Century* (Ref. 49). For Heisenberg, an extensive bibliography can be found at Cassidy's website (Ref. 124).

95. A World Destroyed. Hiroshima and the Origins of the Arms Race, M. J. Sherwin (Vintage, New York, 1987). Examines the circumstances and considerations that led to the bombings of Hiroshima and Nagasaki and the relationship between the history of the atomic bomb and the postwar arms race and U.S. atomic policy. Several important documents such as Bush and Conant's memorandum to Henry Stimson on postwar handling of atomic bombs, Groves's report on the Trinity test, Interim Committee minutes, excerpts from the Franck report, and War Planning Casualty Estimates for the proposed invasion of Japan are reproduced in the appendices. (E)

96. Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940, S. I. Schwartz, ed. (Brookings Institution Press, Washington, D.C., 1995). This massive study analyzes the costs of the U.S. nuclear weapons program from 1940 to 1996. Costs of research, development, testing, deployment, command and control, defense and dismantling of weapons systems, waste cleanup, compensation for persons harmed by the production and testing of nuclear weapons, and estimated future costs for storing and disposing of waste and dismantling and disposing of surplus materials are considered. Costs are given in both then-year and adjusted-to-1996 dollars. Spending on the nuclear weapons complex exceeded all other government spending except for non-nuclear national defense and social security. The bottom-line total in 1996 dollars is $5.8 trillion, which represents 29% of all military spending between 1940 and 1996 and 11% of all government expenditures during that time. Includes tabulations of the numbers of, yields, and delivery systems of all warhead types from 1945 to 1990. See also Ref. 111. (A)

97. Vanguard of American Atomic Deterrence: The Sandia Pioneers, 1946–1949, J. L. Abrahamson and P. H. Carew (Praeger, Westport, CT, 2002). Following the war, General Groves set out to arrange for the training of a cadre of military officers who would be responsible for storing, maintaining, transporting, and assembling nuclear weapons. The history of this very successful program is related in this book. The authors also relate some of the history of the earliest preparations to deploy American nuclear weapons abroad, specifically in the U.K. (I)

98. Bomb Scare: The History and Future of Nuclear Weapons, J. Cirincione (Columbia U. P., New York,

2007). Cirincione covered how and why nuclear weapons have multiplied and what can be done to slow, stop, and reverse their spread. The first three chapters of this thin volume offer a concise history of nuclear developments up to and including the North Korean test of October 2006; subsequent chapters offer analyses of why states want or do not want to acquire nuclear weapons, the state of world stocks of highly enriched uranium and plutonium, changes in U.S. policy since 9/11, prospects for reducing threats from nuclear weapons, proposed solutions for preventing nuclear terrorism and securing the fuel cycle, and preventing emergence of new nuclear weapons' states. Some issues of physics are garbled. A glossary gives concise definitions of various technical and political terms. (E)

99. Five Days in August: How World War II Became Nuclear War, M. D. Gordin (Princeton U. P., Princeton, 2007). Gordin offered a reinterpretation of the beginning of the nuclear age, arguing that the almost mythical "special" status of atomic bombs was a consensus constructed after the quick surrender of Japan following their use. This thesis is questionable in that various political and military figures (notably Henry Stimson) did appreciate the revolutionary nature of the new weapons and had communicated such sentiments to President Truman. Gordin's book is of interest, however, for its study of the history of Tinian Island and its capture by the Marines in July 1944. Descriptions of physics are erroneous in places. (E)

100. Red Cloud at Dawn: Truman, Stalin, and the End of the Atomic Monopoly, M. D. Gordin (Farrar, Strauss and Giroux, New York, 2009). This companion volume to Ref. 99 analyzes the key decisions regarding nuclear weapons policy during the period of the U.S. monopoly on such weapons between 1945 and 1949, including the evolution of the ill-fated Baruch plan. Interesting for its study of the origin of the United States' airborne system for detecting atmospheric radioactivity. Some of the physics errors appearing in Ref. 99 are repeated in this work. (E)

101. The Bomb: A New History, S. M. Younger (Ecco/HarperCollins, New York, 2009). Younger worked on nuclear weapons research and development as a Senior Fellow at Los Alamos National Laboratory and served as the Director of the Defense Threat Reduction Agency from 2001 to 2004. This book is a fairly brief review of the physics of nuclear weapons from the discovery of fission through the development of the hydrogen bomb, the history of treaties concerning nuclear weapons, the state of current arsenals, targets and targeting, how nuclear weapons can be replaced with conventional ones for many missions, proliferation, defenses against various modes of nuclear attack, force maintenance, and the role of nuclear weapons in the 21st century. On the rationale of desiring that his access to classified material not be interpreted as lending credence to any open source, Younger gave no references, few hard numbers, and extremely simplified diagrams. He concluded by advocating what he described as a "moderate" position on U.S. nuclear forces: 1000–2000 warheads consisting of two designs of each of two yield classes, about 10 and 500 ktons. (E)

102. "The decision to use the atomic bomb," H. L. Stimson, Harper's Magazine **194** (1161), 97–107 (1947). As Secretary of War under Presidents Roosevelt and Truman, Stimson administered the Manhattan Project and served both Presidents as senior advisor on the military employment of atomic energy until his resignation in late September 1945. In this article, he gave a personal account of the circumstances that led to the use of the bombs, arguing that no other course was plausible. As discussed in Ref. 53, however, this article was actually prepared by a number of writers and presents a selected argument. (E)

103. "Research in Germany on the technical application of atomic energy," W. Heisenberg, Nature (London) **160** (4059), 211–215 (1947). Heisenberg reviewed wartime research on atomic energy in Germany with particular emphasis on pile experiments. In response to the question of why Germany "made no attempt to produce atomic bombs," he claimed that such a project could not have succeeded under German war conditions. For a different perspective, see Bernstein's analysis of the Farm Hall transcripts, Ref. 106 in MP-1. (E)

104. "Atomic weapons and American policy," J. Robert Oppenheimer, Foreign Affairs **31** (4), 525–535 (1953). In an article published just months before his security-clearance hearing, Oppenheimer analyzed American atomic weapons policy, with particular attention to the debilitating effects of excessive secrecy on public debate. (E)

105. "The hydrogen bomb," L. N. Ridenour, Sci. Am. **182** (3), 11–15 (1950). This article was the first of two published in successive editions of *Scientific American* soon after President Truman's order to the Atomic Energy Commission to pursue work on fusion weapons but before a fusion device had been tested; Ref. 106 comprises the second installment. The articles cover at a semipopular level the physical basis of such weapons (triggering mechanisms, reactions, timescales, and energy release), their anticipated blast, thermal, and radiation effects, strategic and moral considerations, and reflections on the importance of open discussion of policy issues in an informed democracy. For readers seeking an introduction to the physics and history of fusion weapons, these articles are still worth reading. (E)

106. "The hydrogen bomb: II," H. A. Bethe, Sci. Am. **182** (4), 18–23 (1950). Companion paper to Ref. 105. Bethe presented an impassioned discussion of the immorality of fighting even a ruthless enemy with hydrogen bombs, which he characterized as "the greatest menace to civilization." He also developed a compelling argument that the only purpose of hydrogen bomb development for the United States would be in order to prevent its use by the U.S.S.R., and advocated a pledge on the part of America that it would never be the first to use a hydrogen bomb and would use them only if one were used against us or one of our allies—a position identical to current nuclear weapons policy. (E)

107. "Comments on 'The history of the H-bomb'," H. A. Bethe, Los Alamos Sci. **3** (3), 43–53 (1982). Originally written in 1954 in response to inaccurate public treatments of the development of fusion weapons, this article was declassified in 1982. While he does not deal with the Manhattan Project *per se*, Bethe made a number of trenchant comments on Los Alamos during wartime, the postwar development of fission bombs, the development of the H-bomb, and offered personal comments on the necessity of the H-bomb. Also includes a number of criticisms of Peter Goodchild's *J. Robert Oppenheimer: Shatterer of Worlds* (MP-1, Ref. 61). (E)

108. "The paternity of the H-bombs: Soviet–American perspectives." G. Gorelik, Phys. Perspect. **11** (2), 169–197 (2009). Gorelik compared statements from various participants in both the Soviet and American H-Bomb programs to examine claims of the paternity of these devices, concluding that recently disclosed Soviet documents validate Edward Teller's view on this issue. Gorelik further argued that "illusory worldviews" were largely responsible for the intensity of the H-bomb debate in the United States. (E)

109. "From security blanket to security risk: Scientists in the decade after Hiroshima," L. Badash, History and Technology **19** (3), 241–256 (2003). This article explores a taxonomy of the ways in which scientists were viewed (such as saviors, incompetent, disloyal, or irrelevant) in the United States in the decade following the end of World War II. (E)

110. "American physicists, nuclear weapons in World War II, and social responsibility," L. Badash, Phys. Perspect. **7** (2), 138–149 (2005). Examines the development of the concept of social responsibility and its appearance among American scientists both before and after the end of World War II. (E)

111. "U. S. nuclear warheads, 1945-2009." R. S. Norris and H. M. Kristensen, Bull. At. Sci.. **65** (4), 72–81 (2009). This article tabulates the names, delivery systems, design laboratories, operational lifetimes, numbers built, yields, and gives descriptive notes for over 100 types and modifications of over 66,000 nuclear warheads built in the United States between 1945 and 2009. (I)

112. "John von Neumann and Klaus Fuchs: An unlikely collaboration," J. Bernstein, Phys. Perspect. **12** (1), 36–50 (2010). This paper describes a design developed by von Neumann and Fuchs for a combination fission/fusion bomb that introduced the idea of "ionization compression." They filed a patent for the design at Los Alamos in May 1946; Fuchs passed on the design to the Russians in 1948. Bernstein discussed how neither the American nor the Russians made any real use of the design, which he argued could have changed the course of development of both countries' fusion-weapon programs. (I)

113. "A physicist in the corridors of power: P. M. S. Blackett's opposition to atomic weapons following the war," M. J. Nye, Phys. Perspect. **1** (2), 136–1556 (1999). Nye described the life and work of Patrick Blackett, a World War I naval veteran, Nobel-prize winning protégé of Ernest Rutherford, and member of the British MAUD committee who was involved in developing operational research during the war. In 1948, he published a book which criticized the United States' McMahon Act, advocated a neutralist foreign policy for the United Kingdom, argued that conventional and nuclear disarmament should be negotiated in parallel, and took issue with the alleged efficacy of aerial bombing in World War II. While he was vilified in the press and widely regarded as a communist fellow-traveler, his situation contrasted markedly with Robert Oppenheimer's in that he remained a political insider, serving on numerous government committees. By the early 1960s, his positions had come be regarded as much more respectable. (E)

III. VIDEOS AND WEBSITES

114. The U.S. Department of Energy Office of History and Heritage Resources maintains an Interactive History website on the Manhattan Project at ⟨http://www.cfo.doe.gov/me70/manhattan/index.htm⟩. (I)

115. The U.S. Department of Energy and Interior are considering development of a Manhattan Project National Historic Park that would involve sites at Los Alamos, Hanford, and Oak Ridge. Documents relevant to the study can be found at ⟨http://www.cfo.doe.gov/me70/history/NPSweb/manhattan_project_sites.htm⟩. (E)

116. The website of the Los Alamos National Laboratory Bradbury Science Museum can be found at ⟨http://www.lanl.gov/museum⟩. (E)

117. A number of National Nuclear Security Administration documents available under the Freedom of Information Act are available at ⟨www.doeal.gov/opa/FOIAReadRmLinkst.aspx⟩. (A)

118. The Nevada Site Office of the National Nuclear Security Administration offers an online collection of films of nuclear tests conducted between 1945 and 1962 ⟨http://www.nv.doe.gov/library/films/testfilms.aspx⟩. (E)

119. The Harry S. Truman Library and Museum makes available online a collection of documents, diary entries, letters and press releases relevant to President Truman's decision to use atomic bombs ⟨http://www.trumanlibrary.org/whistlestop/study_collections/bomb/large⟩. (E)

120. Material on the life and work of Leo Szilard can be found at ⟨http://www.dannen.com/szilard.html⟩. This site includes a link to documents pertinent to the decision to use atomic bombs on Hiroshima and Nagasaki (MP-1, Ref. 139).

121. Copies of documents pertaining to Robert Oppenheimer's alleged Communist Party membership and spying activities can be found at ⟨http://www.brotherhoodofthebomb.com⟩, the companion website to Gregg Herken's *Brotherhood of the Bomb: The Tangled Lives and Loyalties of Robert Oppenheimer, Ernest Lawrence, and Edward Teller* (MP-1, Ref. 67). (E)

122. The American Institute of Physics Center for the History of Physics (AIP-CHP) maintains a website on the life and work of Ernest Lawrence, ⟨http://www.aip.org/history/lawrence⟩; see especially the link titled "the bomb." (E)

123. Another AIP-CHP website examines the life of Soviet weapons physicist and dissident Andrei Sakharov; ⟨http://www.aip.org/history/sakharov⟩. (E)

124. David Cassidy (Ref. 50) maintained a site on the life of Werner Heisenberg, ⟨http://www.aip.org/history/heisenberg/p01.htm⟩. See particularly the link titled "Heading Fission Research," which includes links to excerpts from the Farm Hall transcripts and material on Heisenberg's 1941 visit to Bohr. This site also includes a link to a complete bibliography of Heisenberg's technical and nontechnical writings. (E)

125. The Atomic Heritage Foundation (AHF; ⟨www-.atomicheritage.org⟩) is a nonprofit organization dedicated to the preservation and interpretation of the Manhattan Project and works with the Department of Energy and the former Manhattan Project communities to preserve historic resources and other aspects of the history. In 2006, the Manhattan Project Heritage Preservation Association (MP-1, Ref. 137) was absorbed by the AHF. (E)

126. The Federation of American Scientists maintains a website where they make available copies of hundreds of Los Alamos Technical Reports and Publications: ⟨http://www.fas.org/sgp/othergov/doe/lanl/index1.html⟩. (A)

127. The B-Reactor Museum Association (⟨http://www.b-reactor.org⟩) is a volunteer group that works with local, state, and federal authorities to preserve the Hanford B reactor and turn it into a publicly accessible museum. Their work has resulted in B-reactor being declared a National Historic Landmark. (E)

128. The National Archives and Records Administration (NARA) makes available for purchase microfilms of records of correspondence between Vannevar Bush and James Conant pertinent to the development of the atomic bomb (publication M1392, 14 rolls), as well as Manhattan Engineer District History documents (publication A1218, 14 rolls). These may also be viewed at various NARA locations around the country. The homepage is ⟨https://eservices.archives.gov/orderonline/start.swe?SWECmd=Start&SWEHo=eservices.archives.gov⟩. (E, I, A)

129. After the war, the Monsanto Co.'s Dayton, Ohio, facility that was established for producing polonium (Ref. 25) was relocated and became known as the Mound Laboratory, and was involved in developing components such as spacecraft radioisotope thermoelectric generators. The Mound Museum collects, preserves, and makes publicly accessible the remaining heritage of the laboratory ⟨http://moundmuseum.com⟩. (E)

130. "Hiroshima," produced by Paul Wilmshurst (BBC, 2005). This DVD is one installment of a 12-disk, 30-h set on the history of WW II. Archival footage and interviews are blended with recreations of meetings, briefings, the work of the *Enola Gay* crew and actions of Hiroshima residents to present a balanced picture of the bombing of Hiroshima. One particularly compelling scene gives a "bomb's-eye view" as Little Boy free-falls for 45 s after being released. (E)

131. "The world of Enrico Fermi." This DVD, distributed by the AAPT, includes a two-part 1970 "Project Physics" documentary on the life and work of Fermi. In rarely seen footage one can hear Fermi's voice describing chain reactions and nuclear power; includes interviews with Laura Fermi, I. I. Rabi, S. Chandrasekhar, Eduardo Amaldi, Franco Rasetti, Harold Agnew, Sam Goudsmit, Herbert Anderson, Philip Morrison, and, in the last month of his life, Robert Oppenheimer. (E)

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