# **Nuclear Winter and the End of the Age of Agriculture**

By Dr. Lawrence Badash

Professor Emeritus of History of Science

Department of History

University of California

Santa Barbara, CA 93106-9410

badash@history.ucsb.edu

Prepared for

The Jeffrey Rubinoff Sculpture Park

MAY 2010 COMPANY OF IDEAS FORUM

**Dr. Lawrence Badash**

University of California, Santa Barbara

Lawrence Badash received a B.S. in physics from Rensselaer Polytechnic Institute in 1956, and a Ph.D. in history of science from Yale University in 1964. He is Professor Emeritus of History of Science at the University of California, Santa Barbara, where he taught for thirty-six years. He has been a NATO Postdoctoral Science Fellow at Cambridge University, a Guggenheim Fellow, Visiting Professor of International Studies at Meiji Gakuin University in Yokohama, Director of the University of California Institute on Global Conflict and Cooperation's Summer Seminar on Global Security and Arms Control, a lecturer on the nuclear arms race at the Inter-University Center of Postgraduate Studies in Dubrovnik, Croatia, a Council member of the History of Science Society, a Member-at-Large of the Section on History and Philosophy of Science of the American Association for the Advancement of Science, and a member of the Executive Committee of the Forum on Physics and Society of the American Physical Society. Badash is a Fellow of the American Physical Society and of the American Association for the Advancement of Science.

His research is centered on the physical sciences of the past century, especially the development of radioactivity and nuclear physics; on the role of scientists in the nuclear arms race; and on the interaction of science and society. Badash has authored or edited six books, including Radioactivity in America, Kapitza, Rutherford and the Kremlin, Scientists and the Development of Nuclear Weapons, and Reminiscences of Los Alamos 1943-1945. He is currently finishing a book on the science and politics of the nuclear winter phenomenon.

This presentation is a contribution to the Jeffrey Rubinoff Sculpture Park *Company of Ideas*, the goal of which is to deepen the public understanding of the sculpture work of Jeffrey Rubinoff. The aim of this paper is to elucidate the development and eventual use of nuclear weapons and the ensuing arms race. This is the finality of what Rubinoff has termed the End of the Age of Agriculture.

Sculptor Jeffrey Rubinoff has advanced the concept that we now live in a period *after* the End of the Age of Agriculture:[1] From the prehistoric invention of agriculture to the end of World War II, people embraced a social contract with what became the ruling warrior class. Wars were fought for arable land and eventually for other resources, while the larger population produced wealth in return for protection. Over millennia, nations came and went, but the relationship proved to be remarkably stable. It ended, however, with the development of strategic bombing during World War II and the advent of nuclear weapons in the war's closing days. As Rubinoff noted, "the fundamental assumptions of the age of agriculture, security of territory as the means to secure food production, must be revised to the era of global vulnerability."[2] The warrior class has become impotent to protect its people. At present, the failed social contract has not been replaced. We struggle to conceive of new institutions.

Into this period of uncertainty the nuclear winter phenomenon was revealed to the public in 1983. It suggests that cities will surely burn in a nuclear war, propelling black smoke and soot high in the atmosphere. Blocked sunlight will fail to warm the Earth's surface and, because of this climatic change of lowered light and temperature and reduced rainfall, agriculture will falter globally. It is all the more important that new political and social institutions be developed quickly to avoid such a calamity.

What were the steps that led to the end of the age of agriculture? What did significant participants think they were doing? Some answers emerge if we

---

[1] See the web site of the Jeffrey Rubinoff Sculpture Park, www.rubinoffsculpturepark.org/coi/Forum Directors Report 2009.pdf, page 4.

[2] Ibid.

focus on the beliefs of scientists, mostly nuclear physicists, about the release of atomic energy. At first they denied the likelihood. Then they expected to control when and if atomic energy would be used. Finally, in frustration, they demanded to be heard concerning their fear that the bomb had become an intolerable weapon. These views were influenced by their initial belief that scientists had rather little impact on society to their eventual recognition that they had made possible the end of civilization.

## Can the Atom's Energy be Harnessed?[3]

Pandora, of Greek mythological fame, incautiously opened a box and allowed to escape the ravages of human mind and body. Only hope remained to comfort mortals. The discovery of nuclear fission at the end of 1938 presented some scientists with a modern counterpart to Pandora's box. Would the splitting of uranium lead to inexpensive energy that might revolutionize the world's economy, or would the product be instead a bomb of awesomely destructive power?

Long before the discovery of nuclear fission, scientists knew that the atom contained a lot of energy. After Henri Becquerel* [* = PowerPoint picture] discovered radioactivity in 1896, and Marie Curie,* Pierre Curie,* and Gustave Bémont discovered the radioactive element radium two years later, scientists recognized the outpouring of energy in the fact that radium glowed in the dark. An American chemist suggested that bicycle lamps would now have lanterns powered by radium.

As early as 1902, the chemist Frederick Soddy,* who worked at McGill University in Montreal with the physicist Ernest Rutherford,* wondered if the enormous amount of energy in the atom derived from the sun. Elaborating on this the following year, Soddy wrote that the Earth "was a storehouse stuffed with explosives, inconceivably more powerful than any we know of, and

---

[3] The pre-history of atomic energy, from the discovery of radioactivity in 1896 to the discovery of fission in 1938, is treated in greater detail in L. Badash, Elizabeth Hodes, and Adolph Tiddens, "Nuclear fission: Reaction to the discovery in 1939," *Proceedings of the American Philosophical Society*, 130 (June 1986), 196-231.

possibly only awaiting a suitable detonator to cause the earth to revert to chaos."[4] Also in 1903, Pierre Curie and Albert Laborde recognized that radium kept itself warmer than its surroundings. Editorial writers, who converted this microscopic laboratory measurement of heat into macroscopic amounts that a layman could understand, noted that the energy in one gram of radium could elevate five hundred tons a mile high, while an ounce could propel a fifty-horsepower automobile at thirty-five miles an hour around the Earth.[5]

Rutherford, the central figure in radioactivity and early nuclear physics, dropped his caution on one occasion and speculated that "could a proper detonator be discovered, an explosive wave of atomic disintegration might be started through all matter . . . ." He thus became associated with the idea that "some fool in a laboratory might blow up the universe unawares."[6] The energy in radioactivity showed itself in the expulsion of rays and particles: the much studied gamma rays and the alpha and beta particles. This energy was many times greater than that released in most chemical reactions. But, as something of a damper, it was recognized that while one atom influenced another in a chemical explosion, this was not the case in an atomic transformation. There, each atom had a statistical probability of rupturing during the average period called its half-life, but the half-life could not be altered.

Pierre Curie, a gentle and sensitive man, used the occasion of his Nobel Prize speech to praise radium's potential to treat cancer, but also to warn that radium could burn healthy tissue. In "criminal hands," he said, "radium could become very dangerous."[7] And so it went for the next decade: Some feared the explosive release of atomic energy—some 2.5 million times the energy in an equal weight of TNT—while others looked to its controlled release to be used by industry, or rested calmly because there was no obvious way to tap the atom.

---

[4] F. Soddy, "Some recent advances in radioactivity," *Contemporary Review*, 83 (May 1903), 708-720, quote on 720.

[5] *Potsdam* (New York) *Courier*, (9 Dec. 1903).

[6] W. C. D. Whetham, "Matter and electricity," *Quarterly Review*, 199 (Jan. 1904), 100-126, first quote on 126. A. S. Eve, *Rutherford* (Cambridge: Cambridge University Press, 1939), 102.

[7] P. Curie, "Radioactive substances, especially radium," in *Nobel Lectures, Physics, 1901-1921* (Amsterdam: Elsevier, 1967), 78.

By the 1920s, Rutherford's recognition that the atom has a nucleus, Albert Einstein's* $E = mc^2$ relationship equating mass and energy, and the increasingly accurate atomic weight measurements provided by F. W. Aston's* mass spectrometer, allowed calculations to be made of the energy released in specific nuclear transformations. This stimulated still more speculation and provided the basis for calls for a research moratorium. Scientists were depicted as socially irresponsible; they cared more for knowledge than for humanity. Robert Millikan,* a noted physicist and the man credited with building the California Institute of Technology, rejected the idea of a research moratorium. He reasoned that the heavy elements, among which the first radioactive elements were found, comprise less than one percent of all matter, too trivial a fraction for worry. (Of course, he was incorrect about the willingness to mine such poor ores.) A devout man, Millikan also argued that "the creator has put some fool-proof elements into his handiwork and that man is powerless to do any titanic physical damage."[8] (Again, Millikan was incorrect. By the way, note that scientists are known to make statements that sound like scientific conclusions but are really no more than opinions.)

Despite the nay-sayers, speculation about harnessing atomic energy was rekindled with each scientific advance. This occurred, for example, when John Cockcroft and E. T. S. Walton* built a particle accelerator in Rutherford's Cavendish Laboratory at Cambridge University in 1932 and were able to disintegrate the element lithium. This device and other atom-smashing machines, such as the cyclotron invented by Ernest Lawrence* at the Berkeley campus of the University of California, made control of the atom seem much closer. Such is the context for Rutherford's headline-making comment at the 1933 meeting of the British Association for the Advancement of Science: "Any one who says that with the means at present at our disposal and with our present knowledge we can utilize atomic energy is talking moonshine."[9] He was irritated by the speculation and wanted to shut it down. A year later, Einstein* was equally critical of success, calling the effort "fruitless."[10]

---

[8] R. A. Millikan, "Alleged sins of science," in *Science and the New Civilization* (New York: Scribner's, 1930), 52-86, quote on 58.

[9] *New York Times*, (12 Sept. 1933), 1.

[10] *Pittsburgh Post-Gazette*, (29 Dec. 1934), sect. 2, p. 1.

For four decades the argument went back and forth. Nor was it a minor issue, as it attracted the attention of a host of distinguished scientists, including more than a dozen who were or would become Nobel laureates (Rutherford, Pierre Curie, William Ramsay, Soddy, Aston, Enrico Fermi, Millikan, I. I. Rabi, Lawrence, Einstein, Lev Landau, Frédéric Joliot-Curie, and Niels Bohr).

Yet this public discussion was not, with hindsight, especially innovative or profound. Some of the latest discoveries were incorporated into the arguments—such as the view that the neutron, discovered in 1932 by James Chadwick* in Rutherford's lab, might be the magic bullet needed to split the atom. Other ideas were curiously absent—such as the need for a chain reaction. (But that's largely a chemical process and most of the scientists involved were physicists.) Only the refugee physicist Leo Szilard* pondered the chain reaction, and he placed that in a secret patent assigned to the British Admiralty. He wanted to keep the idea from circulating to Nazi Germany.

Scientists (and the public) lacked a high degree of fanciful thinking, while at the same time many exhibited an almost blind confidence in the future conquest of Nature. This is not meant as criticism of scientists and the public. Rather, it is an effort to emphasize that scientists, even the most creative ones, usually behave as ordinary human beings, and the human condition, thanks to Pandora, is basically one of hope, with few glimpses of distant peaks or even the path toward them.

<u>Reaction by Scientists to the Discovery of Nuclear Fission</u>[11]

After uranium fission was discovered at the end of 1938, Rutherford* was criticized for having poured cold water on the release of atomic energy. The criticism, I feel, is misguided, for Rutherford clearly said that he was discussing the knowledge and the means at their disposal in 1934. He could not have known that a new phenomenon of Nature, nuclear fission, would be revealed more than a year after his death (in 1937). This discovery was made by chemists Otto Hahn* and Fritz Strassmann* in Berlin, and interpreted by physicists Lise Meitner* and Otto

[11] Information in this section is provided in greater detail in Badash, et al., note 2 above.

Frisch,* who had fled Hitler's Germany. Neutrons striking uranium nuclei cause them to split into two roughly-equal particles, in the process converting a substantial amount of mass into energy.

The news traveled across borders rapidly, even before scientific papers were published in the open literature. Physical confirmation of the energy release came quickly. Physicists around the world recognized that an uncontrolled release of energy could yield an explosive of awesome strength, while a controlled release meant that an energy source of great benefit, a nuclear reactor, was possible. Many deplored the possibility of creating such a weapon, but the concept of social responsibility of scientists, although much discussed, was not strong in practice. Few scientists would, for moral or ethical reasons, decline to pursue fission research.

These ideas were discussed in scientific papers and in newspapers; the concepts were not secret. What *was* secret was that projects to achieve bombs and reactors were begun in the United States, in the Soviet Union, and in Germany and Japan. The United States, joined by Britain and Canada, succeeded first in constructing nuclear reactors which, at Hanford, Washington, were used to create a new element, plutonium. At Oak Ridge, Tennessee, the rare but more readily fissionable isotope, uranium-235, was laboriously separated physically from the more abundant isotope, uranium-238, with which it is chemically identical. And at Los Alamos, New Mexico, J. Robert Oppenheimer* and his teams of scientists and engineers fashioned the U-235 and plutonium into bombs that were dropped on Hiroshima and Nagasaki, respectively, in August 1945.

As suggested above, in the early years of the Manhattan Project, scientists rarely questioned the morality of creating a new weapon. Virtually none declined to investigate if nuclear fission could be turned into a bomb. Indeed, they rather doubted that they would succeed, and thought that the moral issues involved would remain a burden to be faced by their students, whose generation might be the one to harness atomic energy. For them, staying ahead of any possible success by the Germans was paramount. When the Project appeared likely to succeed, the pressure of work again banished moral questions from their minds. Only when research and development activity slackened at the sites other than Los Alamos did some scientists focus on the larger picture. And only physicist Joseph Rotblat* left Los Alamos before the bomb was completed; he had come to prevent Hitler from getting nuclear weapons first, and Germany's surrender meant that the bomb would not be used in Europe.

The Metallurgical Laboratory at the University of Chicago was home to several European refugees whose protests became famous. In efforts to avoid bombing civilians, or at least to give the Japanese government an opportunity to witness a test explosion and then surrender, Leo Szilard had an audience with secretary of state designate James Byrnes, contacted Supreme Court Justice Felix Frankfurter, and circulated a petition among scientists. Nobel laureate James Franck* chaired a committee at the Chicago lab that produced a famous report to the secretary of defense, again seeking alternatives to bombing civilians.[12] In the lone moral protest at the Los Alamos lab, physicist Robert R. Wilson* got Oppenheimer's permission to hold an open discussion for the scientists.[13]

Reaction by Scientists to the Acquisition and Use of Nuclear Weapons

President Truman announced the destruction of Hiroshima soon after it occurred. Newspapers and journals of opinion had a feeding frenzy in the months afterward, a discussion to which many scientists contributed. While the great majority believed that construction of the atomic bomb was necessary, virtually all were appalled by its ability to demolish a city. Although he never expressed remorse for his central role in directing the Los Alamos Laboratory, Oppenheimer* captured the widespread feeling in a speech in 1945 when he said, "We have made a thing, a most terrible weapon, that has altered abruptly and profoundly the nature of the world. We have made a thing that by all the standards of the world we grew up in is an evil thing."[14]

While governments and the military in several countries felt obliged to construct nuclear weapons, scientists were among the leaders in trying to stuff the nuclear genie back into its bottle.

---

[12] The Franck Report may be read at http://fas.org/sgp/eprint/franck.html.

[13] M. Palevsky, *Atomic Fragments: A Daughter's Questions* (Berkeley: University of California Press, 2000), 135-137, 140-143.

[14] J. R. Oppenheimer, "Atomic weapons," *Proceedings of the American Philosophical Society*, 90 (Jan. 1946), 7.

Many who had worked on the bomb project felt that their views on policy issues were not irrelevant.[15] Initially, the public seems to have welcomed the informed voice of scientists in the political arena, additionally impressed by a profession whose pursuit is truth.[16] Challenging military control of the atom in 1945-1946, scientists "alone have faced the puzzle of the bomb socially and realistically," according to an editorial in the *New York Times*. Yet, on the same editorial page, another writer noted that "Not even the fact that a scientist has had a share in making the atomic bomb qualifies him to map national policy or read the future . . . ."[17] Nonetheless, American scientists were successful in helping to fashion the Atomic Energy Act of 1946, strong testimony to their political acumen. They were far less successful in moving the great powers to place all control of nuclear weapons in the hands of the newly-formed United Nations.[18]

Scientists in general (at least those who were vocal) were unhappy with use of the atomic bomb. Not so the public. Months after the end of the war, American citizens remained bitter and blood-thirsty against the Japanese. A survey in *Fortune*, a magazine of the business community, showed that 53.5 percent were satisfied with the bombs' use over two Japanese cities, while an additional 22.7 percent wished that even more atomic bombs could have been dropped before hostilities ceased. Thus, more than three-quarters of Americans surveyed approved of using nuclear weapons against Japanese cities.[19]

Several prominent scientists, by contrast, joined publicly to express their rejection of the bomb in future conflicts. *One World or None*, a popular book that sold more than one million copies, was a collection of essays by Albert Einstein, Niels Bohr, Arthur Compton, Robert Oppenheimer, Leo

---

[15] E. Shils, "Freedom and influence: Observations on the scientists' movement in the United States," *Bulletin of the Atomic Scientists*, 13 (Jan. 1957), 13-18, on 13.

[16] D. Hawkins, "Should the scientist take part in politics?" *New York Times Magazine*, 13 (16 June 1946), 44-46.

[17] Editorials "Challenge of the bomb," and "Topics of the Times," *New York Times*, 6 (21 Oct. 1945), 8.

[18] A. K. Smith, *A Peril and a Hope: The Scientists' Movement in America, 1945-47* (Chicago: University of Chicago Press, 1965).

[19] E. Roper, "The Fortune survey," *Fortune*, 32 (Dec. 1945), 303-310, on 305.

Szilard, Harold Urey, Eugene Wigner, Edward Condon, Hans Bethe, Irving Langmuir, and others. Their major theme was that only international control of the bomb could prevent an arms race. Nuclear weapons were too terrible to be used again.[20] The always eloquent Robert Oppenheimer, in a speech at MIT in 1947, encapsulated for many scientists their torment when he remarked that "physicists have known sin."[21]

In the post-World War II period Manhattan Project scientists organized into the Federation of Atomic Scientists, which soon enlarged its membership by evolving into the Federation of American Scientists. The FAS is alive still, having over the decades embraced environmental and social concerns in addition to nuclear issues. For all these years it has been a highly respected voice of moderation, focused upon Capitol Hill, the media, and the scientific community. For a brief period, the Emergency Committee of Atomic Scientists* acted as a fund-raiser for such efforts. With Albert Einstein its very visible chair, letters soliciting donations were hard to reject. During this half century and more the *Bulletin of the Atomic Scientists* has also flourished, matching the FAS in raising its eyes from nuclear matters to comment also on environmental and social problems. The *Bulletin* has a worldwide readership which watches closely the clock on the magazine's cover for the number of minutes to Armageddon at midnight.*

In addition to these persistent examples of scientists embracing the cause of nuclear disarmament, or at least arms control, a few other specific cases stand out. In the autumn of 1949, faced with evidence that the Soviet Union had successfully tested its first atomic bomb, the United States pondered its reaction. Foremost among the suggestions was pursuit of the so-called super bomb, labeled a hydrogen bomb because it worked by fusing light atoms of hydrogen (compared with the fission of heavy atoms of uranium and plutonium in atomic bombs). Whereas atomic bombs have a practical limit of explosive power (around 1 MT), when the pieces are blown far enough apart to stop the chain reaction, there is no theoretical limit to the explosive power of hydrogen

[20] D. Masters and K. Way (eds.), *One World or None: A Report to the Public on the Full Meaning of the Atomic Bomb* (New York: McGraw-Hill, 1946).

[21] J. R. Oppenheimer, "Physics in the contemporary world," *Technology Review*, 50 (Feb. 1948), 201-204, 231-238, quote on 203.

bombs, other than the weight limit of the airplane or missile needed to carry the bomb. Estimates of the explosive power of "practical" H-bombs were about a thousand times that of A-bombs.

The US Atomic Energy Commission (AEC) had a distinguished board of scientific advisors called the General Advisory Committee (GAC). Leading it was the ubiquitous J. Robert Oppenheimer, who seemed to chair or write the reports for a number of government committees. The GAC report, in October 1949, was unanimous in urging the AEC *not* to develop hydrogen bombs. Such weapons were tools for "exterminating civilian populations;" in other words, these scientists argued that "a super bomb might become a weapon of genocide." In an annex, physicists Enrico Fermi* and I. I. Rabi* introduced questions of morality. They wrote that

> It is clear that the use of such a weapon cannot be justified on any ethical ground which gives a human being a certain individuality and dignity even if he happens to be a resident of an enemy country. It is evident to us that this would be the view of peoples in other countries. Its use would put the United States in a bad moral position relative to the peoples of the world.

While scientific advisors were not expected to advance ethical arguments, Fermi and Rabi nonetheless felt obliged to emphasize that "It is necessarily an evil thing considered in any light."[22] President Truman obviously listened to other advice and research accelerated on fusion weapons, with successful testing of a device in the early 1950s. But this event serves as an example of the profound moral turbulence in which scientists found themselves.

Several years later, the discoverer of nuclear fission, chemist Otto Hahn,* wrote an article on the misuse of atomic energy. These words of 1954 were widely reprinted and also read on the radio in Germany and abroad. The next year Hahn was instrumental in organizing the Mainau Declaration, a statement criticizing nuclear weapons, which ultimately was signed by more than fifty Nobel laureates. Critical of the West German government's willingness to have NATO

---

[22] H. F. York, *The Advisors: Oppenheimer, Teller, and the Superbomb* (San Francisco: W. H. Freeman, 1976). The 1949 GAC report may be read at http://www.atomicarchive.com/Docs/Hydrogen/GACReport.shtml.

forces store nuclear weapons on German territory, and the government's unwillingness to disclaim any desire to possess such weapons itself, Hahn and seventeen other prominent scientists stated publicly in 1957 that they would not participate in the research and development or use of nuclear weapons. Chancellor Konrad Adenauer rebuked them, and there is no evidence that the scientists had any effect. There is, however, the possibility that they convinced some of their younger colleagues to reject work on weapons.[23]

The Bertrand Russell-Albert Einstein Manifesto appeared in 1955.[24] This highly publicized document criticized nuclear weapons and called for an international conference of scientists to assess the problem. It took a year and a half for this meeting to take place, and the organization formed took its name from its original venue, in Pugwash, Nova Scotia.[25] Twenty-two scientists attended this first Pugwash Conference on Science and World Affairs, beginning a tradition that has lasted more than half a century. Participants came not as official representatives of their country, but as individuals. Freed of official constraints, they often were able to agree on various arms control issues, and the beauty of this approach was that their governments were quite interested in their proposals and appreciated this non-diplomatic line of communication.[26] In 1995, Pugwash shared the Nobel Peace Prize with its long-time leader, physicist Joseph Rotblat.

The second half of the 1950s also saw an international campaign to collect the signatures of scientists on a petition opposing the atmospheric testing of nuclear weapons. Both superpowers had developed the hydrogen bomb and were trying to perfect their designs. Hundreds of tests were conducted, the vast majority being explosions atop towers or of bombs dropped from aircraft. The United Kingdom successfully tested its atomic bomb in 1952 and hydrogen bomb in 1957; France acquired the A-bomb in 1960. These added a few more atmospheric explosions to the total. Bomb debris contains the residue of unfissioned uranium and plutonium and the

---

[23] O. Hahn, *Otto Hahn, My Life* (London: MacDonald, 1970), 219-226. "German physicists protest nuclear weapons," *Science*, 125 (1957), 876. For Mainau, see *New York Times*, (16 July 1955), 3.

[24] For Russell-Einstein, see *New York Times*, (10 July 1955), 1 and 24.

[25] For the background to the first Pugwash conference, see www.pugwash.org/about/conference.htm.

[26] J. Rotblat, *Scientists in the Quest for Peace: A History of the Pugwash Conferences* (Cambridge, MA: MIT Press, 1972).

weapon casing, but most importantly consists of the fragments produced when uranium and plutonium fissions or splits. These heavy elements break apart into two almost equal pieces (plus the neutrons needed for the chain reaction), meaning that the fragments are elements that lie in the middle of the periodic table. Usually they are radioactive. Winds blow this radioactive debris to great distances; if the mushroom cloud rises to the stratosphere, the radioactivity may circle the globe. Such fallout was detected in many places, such as in drinking water and on pasture land, and notably dusted the Japanese fishing boat "Lucky Dragon," contaminating its tuna catch. The boat happened to be downwind of an American H-bomb test at Bikini Atoll in March 1954. Countries around the globe became concerned about public health.

American chemist Linus Pauling,* who had not worked on nuclear weapons, led the efforts among scientists to force members of the "nuclear club" to move their testing underground, or, better still, stop altogether. In 1957, he collected some two thousand signatures and sent the petition to President Eisenhower and to the United Nations. This was headline material, and politicians who favored testing (allegedly, to keep the American arsenal strong) endeavored to paint Pauling as a Communist, a charge he denied under oath. Nonetheless, he was denied his passport, denounced by the head of the House Committee on Un-American Activities, and subpoenaed by a Senate investigatory committee. Pauling* expanded his petition to include scientists worldwide, and by early 1958 sent some nine thousand names to the United Nations. The US and the USSR agreed to a moratorium on atmospheric testing in 1958, and signed the Limited Test Ban Treaty in 1963, which permitted testing only underground (banning it in the atmosphere, in space, and under water). The signatories had perfected the means to test underground and were happy to sidestep the mounting criticism surrounding fallout. For his efforts, the Nobel Peace Prize (for 1962) was awarded to Pauling in 1963. (He had won the Nobel Prize in Chemistry in 1954.)[27]

Linus Pauling and Otto Hahn may have been outsiders, those whose advice governments might choose to ignore. But insiders also protested nuclear weapons and the conduct of the arms race.

---

[27] T. Hager, *Force of Nature: The Life of Linus Pauling* (New York: Simon and Schuster, 1985). For Pauling's petition, see the Oregon State University Library web site http://osulibrary.oregonstate.edu/specialcollections/coll/pauling/peace/narrative/page27.html.

Physicists Hans Bethe* and Richard Garwin* were consummate insiders, having contributed to the successful development of the American arsenal and having served on important advisory committees. Their public protest in 1968 against development of the Anti-Ballistic Missile (ABM), therefore, was stunning, for it indicated that protest from within the administration was fruitless. *Scientific American*, a leading magazine in interpreting scientific advances for the layman, also presented articles on the interaction of science with society. The growing ABM controversy was ideal for its pages. Bethe and Garwin argued that the ABM could easily and inexpensively be overwhelmed simply by increasing the number of attacking missiles. This had recently become easier to accomplish, as missiles could carry more than one warhead, a capability known as MIRVing (Multiple Independently-targetable Reentry Vehicles). In addition, this response would "ratchet" up the arms race considerably.[28] While newly-elected President Nixon endorsed construction of ABM, he made the defensive weapon a significant part of his style of "bargaining from strength," and his administration in 1972 signed with the Soviet Union the ABM Treaty, which limited construction so as to make the system near-worthless.[29]

Another insider was Andrei Sakharov,* the brilliant theoretical physicist credited with a major role in the development of the Soviet Union's hydrogen bomb. Initially willing to work on weapons because he felt he was helping his country resist domination by the United States, he lived for two decades within the closed world of the weapons laboratories. But his moral conscience developed and he became increasingly concerned with the danger of mass destruction, should such weapons be used. In 1962, Sakharov personally telephoned Premier Nikita Khrushchev to warn—unsuccessfully—that a scheduled test would endanger many people with its radioactive fallout. Nonetheless, his influence helped to move the Soviet Union toward the Limited Test Ban Treaty of 1963. Now increasingly outspoken, Sakharov's critical writings were circulated in *samizdat* and found their way to publication in the West. In 1968, he lost his

[28] H. A. Bethe and R. L. Garwin, "Anti-ballistic missile systems," *Scientific American*, 218 (1968), 21-31. S. S. Schweber, *In the Shadow of the Bomb: Bethe, Oppenheimer, and the Moral Responsibility of the Scientist* (Princeton, NJ: Princeton University Press, 2000).

[29] For the ABM Treaty, see http://www.fas.org/nuke/control/abmt/.

security clearance and was regarded as one of his country's leading political dissidents. For his courageous actions he was awarded the Nobel Peace Prize in 1975.[30]

My goal, so far, has been to illustrate that, among those scientists who made public comments about nuclear weapons, most have opposed their stockpiling, testing, and use. From their belief, before World War II, that they had little influence on society, their position evolved to where they felt that the policy changes they recommended were mandatory.

Another evolution was in the landscape of American science. Before WWII, the federal government supported research in agriculture, oceanography, health, and geological surveys. Most were in support of economic activity. Basic researchers knew that it was futile to seek funding from Washington. After WWII, however, new social and political structures evolved. These unworldly academic scientists had produced radar, the proximity fuse, and most prominently the atomic bomb; it was now clear that basic research could lead to desired applications. More and more the federal government undertook to fund basic research, as no university or foundation was wealthy enough. The Office of Naval Research, the Atomic Energy Commission, the National Science Foundation, national laboratories such as Brookhaven, "think tanks" such as the RAND Corporation, and other organizations joined the existing National Institutes of Health and various military agencies to absorb millions and then billions of dollars. After the US was embarrassed in October 1957 by the Soviet launch of Sputnik, the first artificial satellite of the Earth, President Eisenhower created the position of presidential science adviser and a President's Science Advisory Committee. Science became institutionalized in the White House.[31]

## Nuclear Winter[32]

[30] A. Sakharov, *Progress, Coexistence, and Intellectual Freedom* (New York: Norton, 1968). For biographical information, see www.aip.org/history/sakharov/ and www.nobelprize.org/nobel_prizes/peace/laureates/1975/sakharov-autobio.html.

[31] Zuoyue Wang, *In Sputnik's Shadow: The President's Science Advisory Committee and Cold War America* (New Brunswick, New Jersey: Rutgers University Press, 2008).

[32] L. Badash, *A Nuclear Winter's Tale: Science and Politics in the 1980s* (Cambridge, MA: MIT Press, 2009).

Now let me turn to nuclear winter, which provides another illustration for the theme of this conference, that warfare is no longer a means for conquering land and people. In addition to the physical destruction caused by the blast and heat of a nuclear explosion, and the terrible medical problems caused by radiation from the detonation (X-rays, gamma rays, alpha and beta particles, thermal radiation) and by radioactive fallout, nuclear weapons have the potential to alter the climate. This could lead to the destruction of civilization.

Curiously, the nuclear winter phenomenon was discovered not by scientists at the nation's nuclear weapon laboratories (Los Alamos and Livermore), but by scientists at a lab of the National Aeronautics and Space Agency, a private defense contractor, and a university. This team of five men had a broad range of interests, and brought to bear on the problem information from the fields of nuclear weapons effects (of course), particle microphysics, atmospheric chemistry, fire and smoke research, volcanic eruptions, ozone depletion, planetary studies, and dinosaur extinction.

Their computer simulations of various possible war scenarios, in which cities would inevitably be targeted and burned, suggested that much black smoke and soot would be lofted. It would remain high in the atmosphere, above most of the clouds that normally provide rain to wash particulates out of the air. As sunlight was absorbed by this layer, the Earth's surface would cool markedly. Temperatures might be tens of degrees Celsius below normal, allowing fresh water in many locales to freeze, and this climatic change could last for months.* [show entire NW PowerPoint here]

In the few years after this first announcement of nuclear winter, near the end of 1983, computer models were greatly improved (1-D to 3-D, day-night and seasonal changes instead of averages), more accurate data were entered into the programs, and many assumptions were tested. The overall result was that temperatures would not drop as much as initially calculated nor last as long. Nonetheless, the climatic insult remained severe. In the United States, the National Academy of Sciences conducted a major review of the field and found that it could not deny that the nuclear winter effect might occur.

Internationally, an even larger review was executed. This was done by the Scientific Committee on Problems of the Environment (SCOPE), an agency of the International Council of Scientific Unions (ICSU). Its report, released in the latter part of 1985, reconfirmed the possibility that the nuclear winter effect might occur. But the report also moved in a strikingly new direction, for it studied the biological effects of nuclear winter conditions. The investigation of biological effects had been adamantly opposed by the administration of President Ronald Reagan, which really wanted the issue to go away, for it interfered with its arms modernization designs.

Some 300 scientists from around the world contributed to the SCOPE physical and biological studies. They enumerated the many physical stresses on the environment, such as acute and chronic climate change, global and local fallout, ultraviolet light, toxic aerosols, and so on. Then they looked at the effects of such stresses on natural ecosystems and on agriculture, with emphasis on the latter because of its greater sensitivity and its importance for humans. SCOPE's goal was to evaluate the vulnerability of humans to disruptions in the availability of food.

The 200 biological scientists recognized that natural ecosystems were inadequate to feed Earth's population. Without the benefits of agriculture, less than one percent of humanity could be supported. They studied the vulnerability of crops to temperature variations, agricultural production and consumption records, import and export systems, and dietary patterns. For example, rice consists of more than 80 percent of the diet of nearly two billion people. The scientists concluded that darkness and cooler temperatures were but preludes to the collapse of agriculture in the Northern Hemisphere.

Assuming a springtime or summer war, the next growing season would be lost. For a war that occurred in autumn or winter, the agricultural losses would be less, but still significant. Many growing plants would be killed by a freeze. But a temperature drop of only 3-4 degrees Celsius (far less than the 35 degrees C drop predicted in the first nuclear winter study) would shorten the growing season and curtail the cultivation of wheat in Canada, in the northern part of the US, and in the Soviet Union. Yields of rice, corn, and soybeans would suffer similar reductions with a comparably small reduction in temperature at a critical time.

Lowered temperatures would not be the only problem facing agriculture. Drought could affect India, Southeast Asia, China, Japan, and the African Sahel, as monsoon rain patterns were disrupted. Non-combatant India alone might suffer more fatalities from starvation than would the US and USSR from the direct effects of explosions. Rice production could end in the Northern Hemisphere and possibly also in the Southern Hemisphere.

Uncontrolled fires, increased ultraviolet light, toxic gases, and radioactivity would also imperil agriculture wherever it continued. Humanity would not perish, but with one-to-four billion people thrust into starvation (out of an estimated 4.6 billion people on Earth) it would experience the most staggering blow in its history. Forget Hiroshima and Nagasaki, the biology team's co-leader counseled. More accurate images of nuclear war were those of famine-stricken Sudan and Ethiopia. Even if climatic conditions returned to normal in a year, the lack of seed stocks, farm animals, pollinators, fertilizer, pesticides, tractor fuel, irrigation equipment, and other farming needs could easily condemn agriculture to a slower revival, on the order of several years.

What would happen to a country with a good six-month supply of food? Would half the population be given rations for a year, until the next harvest, or would the entire nation eat for half a year and then starve? The latter is more likely, as history shows famine often associated with siege.[33]

Some veterans of nuclear winter studies a quarter century ago have recently revisited the problem. Using more powerful computers and improved climate models, they have the ability now to examine far longer time periods, look beyond the stratosphere above Earth, and include the effects of the oceans. They conclude that their calculations from the 1980s were correct: a nuclear winter condition would likely occur. Their new insights are that the climatic change would last at least a decade, much longer than previously estimated, and that a regional war—such as one between India and Pakistan—could ignite a global disaster. This would not require the much larger arsenals of the United States and Russia.[34]

---

[33] L. Badash, note 31, 209-214.

[34] A. Robock and O. B. Toon, "Local nuclear war, global suffering," *Scientific American*, 302 (Jan. 2010), 74-81.

Nuclear winter has shown that a substance as tenuous as smoke could wreak havoc on a far greater fraction of Earth's living creatures than previously believed.

## Conclusion

As I have tried to illustrate, scientists found and accepted their moral role in society after World War II. That does not, however, mean that their influence is great. With few exceptions, scientists have been "on tap, not on top." They have been available to do the bidding of the politicians, but have rarely held political power themselves. (I count just two secretaries of defense and three congressmen who were scientists.) We would do well to listen to their counsel, but I think that we cannot rely only on scientists to lead us into a better age.

As Rubinoff has argued, the rewards of large-scale war are no longer agricultural land and population, or even mineral resources. (The old system probably still functions in some less-developed countries.) I might add that the rewards are not even the contemporary versions of economic, political, or psychic wealth. These too are susceptible to the ravages of nuclear weapons and strategic bombing. Note, however, that preparing for war is more lucrative and less dangerous than fighting a war. Defense industries consume a giant slice of the US federal budget. I think it is likely that a nuclear attack will occur only by accident, by miscalculation (fear of an attack and trying to preempt it), or by gross stupidity. Deterrence is the rationale most cited for having nuclear weapons, and most military officers believe (I'm told) that if they are used, we have lost the game.

Who benefits from our current situation? Who are the warriors today? Our political leaders posture a lot, but never lead troops into battle or place themselves in harm's way by other means. In the armed services, there are no sword-wielding horsemen leading a charge or sailors crying out "damn the torpedoes." Military and civilian (e.g., CIA) leaders today are often middle-aged desk pounders, sometimes with PhDs, who manage conflict from afar (via Predator drones, robots or warbots, etc.).[35] And they contract out to private corporations many functions that

---

[35] P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (New York: Penguin, 2009).

formerly were performed by the military (feeding and supplying US troops in Iraq, Blackwater's provision of security, etc.). All profit from the present system and are unlikely to encourage much change.

To reach a new age in which we are safer, nuclear weapons must be abolished. Smaller nuclear nations are not likely to move in this direction without major reductions by the United States and Russia. We may be encouraged by recommendations for a world free of nuclear weapons by some prominent individuals who once advocated having a substantial arsenal. Former secretaries of state Henry Kissinger and George Shultz, former secretary of defense William Perry, and former senator Sam Nunn have attained such enlightenment in recent years, and have succeeded in attracting support from a number of other former officials. They also counsel that deterrence is no longer meaningful.[36] US President Barak Obama won the Nobel Peace Prize in 2009 for his articulation, earlier that year in Prague, of a world without the threat of nuclear Armageddon.

The Spring of 2010 brought a flurry of encouraging activity on nuclear issues. On 6 April the Obama administration released its Nuclear Posture Review, which explains US policy on the use or threat to use nuclear weapons. Notably, the circumstances under which such actions might occur are more limited than before.

On 8 April Russia and the United States signed a new Strategic Arms Reduction Treaty (START). It further reduces the number of allowed nuclear warheads to 1550, and delivery vehicles (ICBMs, submarines, aircraft) to 700, with 100 in reserve. Certainly it is a step in the right direction, but critics argue that it's a small step; both superpowers have far more weapons than what is considered to be a minimum deterrent. The treaty has been submitted to the US Senate, where treaties often remain unratified. Some Republican senators have expressed fear that the reductions specified would leave the US with inadequate protection.

---

[36] G. Shultz, W. Perry, H. Kissinger, and S. Nunn, "Kissinger, Shultz, Perry, and Nunn call for a world free of nuclear weapons," *Wall Street Journal*, (4 Jan. 2007), and their renewed call in *Wall Street Journal*, (15 Jan. 2010).

Building the momentum toward a nuclear-free world, 47 heads of state attended President Obama's call to a Global Nuclear Security Summit, held 13 April in Washington, DC. The focus at this conference was to control both the weapons and weapons materials.

Finally, from 3 May to 27 May 2010, the Nuclear Non-Proliferation Treaty Review is being held in New York. The NPT was signed in 1963 and obliged the existing nuclear-weapon states (US, USSR, UK, France, China) to work towards the elimination of these weapons. The non-nuclear signatories promised not to acquire such weapons and were assured to be free from such attack. All states were to be free to pursue the peaceful uses of nuclear energy. In several reviews of the treaty over the years, the so-called "have not" nations severely criticized the nuclear powers for their glacially slow progress towards ridding themselves of nuclear weapons. North Korea removed itself from the NPT shortly before it tested its first weapon and both Iran and Syria are feared to be moving towards these explosives, so there is pressure for more intensive investigation by the UN's International Atomic Energy Agency (IAEA). Israel, India, and Pakistan—suspected or admitted nuclear states—have not signed the treaty.

These recent events illustrate a strong world-wide desire to eliminate nuclear explosives and to increase the use of nuclear energy from reactors. Yet both are controversial. Some nations (e.g., France) claim their right to maintain their arsenals as a means of self-protection, and that also is an argument heard in the United States. Nuclear energy too has both opponents, who focus on the danger of accidents (Chernobyl, Three Mile Island) and its high cost, and proponents, who cite the relatively small amount of air pollution from nuclear fuel when compared to fossil fuel. The views of scientists have been the focus of this paper, so it is appropriate to note that the Federation of American Scientists (FAS) and the Union of Concerned Scientists (UCS) have consistently opposed nuclear weapons, while their membership seems to have mixed views about the need for nuclear energy. The nuclear arms race dominated the second half of the 20$^{th}$ century. One of the major actors in that drama, the Soviet Union, disappeared in that period, but not the weapons. One may hope that we are now moving more purposefully towards disarmament.

Suggested Reading


Badash, Lawrence, Joseph Hirschfelder, and Herbert Broida (eds.). *Reminiscences of Los Alamos, 1943-1945*. Dordrecht, Holland: D. Reidel Publishing Co., 1980.

Badash, Lawrence. *Scientists and the Development of Nuclear Weapons: From Fission to the Limited Test Ban Treaty, 1939-1963*. Atlantic Highlands, NJ: Humanities Press, 1995; reprinted Amherst, NY: Prometheus Books, 1998.

Badash, Lawrence. *A Nuclear Winter's Tale: Science and Politics in the 1980s*. Cambridge, MA: The MIT Press, 2009.

Ehrlich, Paul, Carl Sagan, Donald Kennedy, and Walter Orr Roberts, *The Cold and the Dark: The World After Nuclear War* (Norton, 1984). This volume comprises the proceedings of the conference at which nuclear winter was unveiled.

Franck, James. *A Report to the Secretary of War, June 1945*. View at http://www.fas.org/sgp/eprint/franck.html.

Harwell, Mark and Thomas Hutchinson. *Environmental Consequences of Nuclear War*, volume 2: *Ecological and Agricultural Effects* (second edition, New York: Wiley, 1989). This is the so-called SCOPE Report on biological effects. It was summarized in a popular volume by Lydia Dotto, *Planet Earth in Jeopardy: Environmental Consequences of Nuclear War* (New York: Wiley, 1986).

Hewlett, Richard and Oscar Anderson. *The New World, 1939-1946. Vol. 1 of a History of the United States Atomic Energy Commission* (University Park: Pennsylvania State University Press, 1962).

Kevles, Daniel, *The Physicists: The History of a Scientific Community in Modern America* (New York: Knopf, 1977; reprinted with a new preface Cambridge, MA: Harvard University Press, 1995).

Palevsky, Mary. *Atomic Fragments: A Daughter's Questions* (Berkeley: University of California Press, 2000).

Rhodes, Richard. *The Making of the Atomic Bomb* (NY: Simon and Schuster, 1986).

Weart, Spencer. *Nuclear Fear: A History of Images* (Cambridge, MA: Harvard University Press, 1988).