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~~(S)~~ History of Nuclear Weapons

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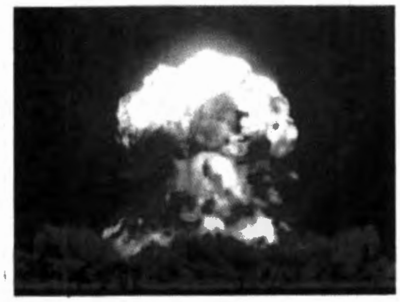
From Intellipedia

(U) The **history of nuclear weapons** chronicles the development of nuclear weapons - devices of enormous destructive potential which derive their energy from nuclear fission or nuclear fusion reactions - starting with the scientific breakthroughs of the 1930s which made their development possible, continuing through the nuclear arms race and nuclear testing of the Cold War, and finally with the questions of proliferation and possible use for terrorism in the early 21st century.



A nuclear fireball lights up the night in a United States nuclear test.

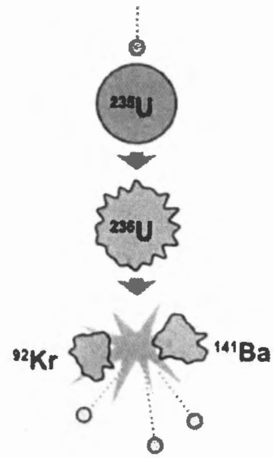
Contents

Introduction

(U) The first fission weapons ("atomic bombs") were developed in the United States during World War II in what was called the Manhattan Project, at which point two were dropped on Japan. The Soviet Union started development shortly thereafter with their own atomic bomb project, and not long after that both countries developed even more powerful fusion weapons ("hydrogen bombs"). During the Cold War, these two countries each acquired nuclear weapons arsenals numbering in the thousands, placing many of them onto rockets which could hit targets anywhere in the world. Currently there are at least nine countries with functional nuclear weapons. A considerable amount of international negotiating has focused on the threat of nuclear warfare and the proliferation of nuclear weapons to new nations or groups. There have been (at least) four major false alarms, the most recent in 1995, that almost resulted in the US or Russia launching its weapons in retaliation for a supposed attack.

Physics and Politics in the 1930s

(U) In the first decades of the twentieth century, physics was revolutionized with developments in the understanding of the nature of atoms. In 1898 , French physicist Pierre Curie and his Polish wife Marie had discovered that present in pitchblende, an ore of uranium, was a substance which emitted large amounts of



In nuclear fission, the nucleus of a fissile atom (in this case, enriched uranium) absorbs a thermal neutron, becomes unstable, and splits into two new atoms, releasing some energy and between one and three new neutrons, which can perpetuate the process.

radioactivity, which they named radium. This raised the hopes of both scientists and lay people that the elements around us could contain tremendous amounts of unseen energy, waiting to be tapped.

(U) Experiments by Ernest Rutherford in 1911 indicated that the vast majority of an atom's mass was contained in a very small nucleus at its core, made up of protons, surrounded by a web of whirring electrons. In 1932, James Chadwick discovered that the nucleus contained another fundamental particle, the neutron, and in the same year John Cockcroft and Ernest Walton "split the atom" for the first time, the first occasion on which an atomic nucleus of one element had been successfully changed to a different nucleus by artificial means.

(U) In 1934 , French physicists Irène and Frédéric Joliot-Curie discovered that artificial radioactivity could be induced in stable elements by bombarding them with alpha particles, and in the same year Italian physicist Enrico Fermi reported similar results when bombarding uranium with neutrons.

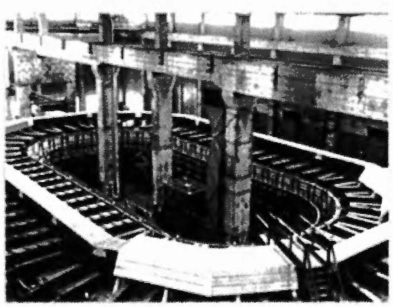
(U) In 1938 , Germans Otto Hahn and Fritz Strassmann released the results of their finding proving that what Fermi had witnessed in 1934 was no less than the bursting of the uranium nucleus: nuclear fission. Immediately afterwards, Lise Meitner and Otto Robert Frisch described the theoretical mechanisms of fission and revealed that large amounts of binding energy were released in the process. Hungarian Leó Szilárd confirmed with his own experiments that along with energy, neutrons were given off in the reaction as well, creating the possibility of a nuclear chain reaction, whereby each fission created two or more other fissions, exponentially releasing energy.

(U) As the Nazi army marched into first Czechoslovakia in 1938, and then Poland in 1939 , officially beginning World War II, many of Europe's top physicists had already begun to flee from the imminent conflict. Scientists on both sides of the conflict were well aware of the possibility of utilizing nuclear fission as a weapon, but at the time no one was quite sure how it could be done. In the early years of the Second World War, physicists abruptly stopped publishing on the topic of fission, an act of self-censorship to keep the opposing side from gaining any advantages.

From Los Alamos to Hiroshima

(U) By the beginning of World War II, there was concern among scientists in the Allied nations that Nazi Germany might have their own project to develop fission-based weapons. Organized research first began in Britain as part of the "Tube Alloys" project, and in the United States a small amount of funding was given for research into uranium weapons starting in 1939 with the Uranium Committee under Lyman James Briggs. At the urging of British scientists, though, who had made crucial calculations indicating that a fission weapon could be completed within only a few years, by 1941 the project had been wrested into better bureaucratic hands, and in 1942 came under the auspices of General Leslie Groves as the Manhattan Project. Scientifically led by the American physicist Robert Oppenheimer, the project brought together the top scientific minds of the day (many exiles from Europe) with the production power of American industry for the goal of producing fission-based explosive devices before Germany could. Britain and the U.S. agreed to pool their resources and information for the project, but the other Allied power - the Soviet Union under Joseph Stalin - was not informed. A massive industrial and scientific undertaking, the Manhattan Project involved many of the world's great physicists in the scientific and development aspects. The United States made an unprecedented investment into wartime research for the project, which was spread across over 30 sites in the U.S. and Canada. Scientific knowledge was centralized at a secret laboratory known as Los Alamos, previously a small ranch school near Santa Fe, New Mexico. Uranium appears in nature primarily in two isotopes: uranium-238 and uranium-235. When the nucleus of uranium-235 absorbs a neutron, it undergoes nuclear fission, splitting into two "fission products" and releasing energy and 2.5 neutrons on average. Uranium-238, on the other hand, absorbs neutrons and does not fission, effectively putting a stop to any ongoing fission reaction. It was discovered that an atomic bomb based on uranium would need to be made of almost completely pure uranium-235 (at least 80% pure), or else the presence of uranium-238 would quickly curtail the nuclear chain reaction. The team of scientists working on the Manhattan Project immediately realized that one of the largest problems they would have to solve was how to remove uranium-235 from natural uranium, which was composed of 99.3% uranium-238. Two methods were developed during the wartime project, both of which took advantage of the fact that uranium-238 has a slightly greater atomic mass than uranium-235: electromagnetic separation and gaseous diffusion - methods which separated isotopes based on their differing weights. Another secret site was erected at rural Oak Ridge, Tennessee, for the large-scale production and purification of the rare isotope. It was a massive investment: at the time, one of the Oak Ridge facilities (K-25) was the largest factory under one roof. The Oak Ridge site employed tens of thousands of employees at its peak, most of whom had no idea what they were working on.

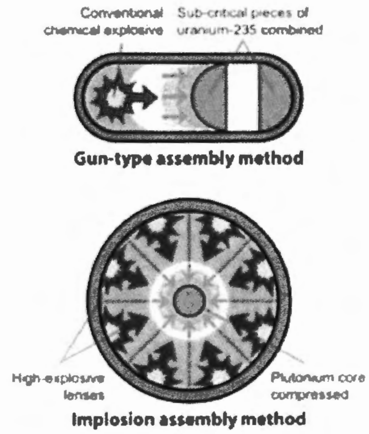
UC Berkeley physicist J. Robert Oppenheimer led the Allied scientific effort at Los Alamos National Laboratory.



Massive new physics machines were assembled at secret installations around the United States for the production of enriched uranium and plutonium.

(U) Though uranium-238 cannot be used inside an atomic bomb, when it absorbs a neutron it transforms first into an unstable element, uranium-239, and then decays into neptunium-239 and finally the relatively stable plutonium-239, an element which does not exist in nature. Plutonium is also fissile and can be used to create a fission reaction, and after Enrico Fermi achieved the world's first sustained and controlled nuclear chain reaction in the creation of the first "atomic pile" - a primitive nuclear reactor - in a basement at the University of Chicago, massive reactors were secretly created at what is now known as Hanford Site in the state of Washington, using the Columbia River as cooling water, to transform uranium-238 into plutonium for a bomb. For a fission weapon to operate, there must be a critical mass - the amount needed for a self-sustaining nuclear chain reaction - of fissile material bombarded with neutrons at any one time. The simplest form of nuclear weapon would be a gun-type fission weapon, where a sub-critical mass of fissile material (such as uranium-235) would be shot at another sub-critical mass of fissile material. The result would be a super-critical mass which, when bombarded with neutrons, would undergo fission at a rapid rate and create the desired explosion.

(U) But it was soon discovered that plutonium cannot be used in a "gun assembly," as it has too high a level of background neutron radiation; it undergoes spontaneous fission to a very small extent. If plutonium were used in a "gun assembly," the chain reaction would start in the split seconds before the critical mass was assembled, blowing the weapon apart before it would have any great effect (this is known as a fizzle). After some despair, Los Alamos scientists discovered another approach: using chemical explosives to implode a sub-critical sphere of plutonium, which would increase its density and make it into a critical mass. The difficulties with implosion were in the problem of making the chemical explosives deliver a perfectly uniform shock wave upon the plutonium sphere - if it were even slightly asymmetric, the weapon would fizzle (which would be expensive, messy, and not a very effective military device). This problem was circumvented by the use of hydrodynamic "lenses" - explosive materials of differing densities which would focus the blast waves inside the imploding sphere, akin to the way in which an optical lens focuses light rays.



The two fission bomb assembly methods.

(U) After D-Day, General Groves had ordered a team of scientists - Project Alsos - to follow eastward-moving victorious Allied troops into Europe in order to assess the status of the German nuclear program (and to prevent the westward-moving Russians from gaining any materials or scientific manpower). It was concluded that while Nazi Germany had also had an atomic bomb program, headed by Werner Heisenberg, the government had not made a significant investment in the project, and had been nowhere near success.

The atomic fireball at the "Trinity" nuclear test secretly rang in the atomic age.

(U) By the unconditional surrender of Germany on 8 May 1945, the Manhattan Project was still months away from a working weapon. That April, after the death of American President Franklin D. Roosevelt, former Vice-President Harry S. Truman was told about the secret wartime project for the first time.

(U) Because of the difficulties in making a working plutonium bomb, it was decided that there should be a test of the weapon, and Truman wanted to know for sure if it would work before his meeting with Joseph Stalin at an upcoming conference on the future of postwar Europe. On July 16, 1945, in the desert north of Alamogordo, New Mexico, the first nuclear test took place, code-named "Trinity," using a device nicknamed "the Gadget." The test released the equivalent of 19 kilotons of TNT, far mightier than any weapon ever used before. The news of the test's success was rushed to Truman, who used it as leverage at the upcoming Potsdam Conference, held near Berlin.

The atomic bombings of Hiroshima and Nagasaki killed tens of thousands of Japanese civilians.

(U) After hearing arguments from scientists and military officers over the possible uses of the weapons against Japan (though some recommended using them as "demonstrations" in unpopulated areas, most recommended using them against "built up" targets, a euphemistic term for populated cities), Truman ordered the use of the weapons on Japanese cities, hoping it would send a strong message which would end in the capitulation of the Japanese leadership and avoid a lengthy invasion of the island. There were suggestions to drop the atomic bomb on Tokyo, the capital of Japan, but concerns about Tokyo's cultural heritage changed the plan. On 6 August 1945, a uranium-based weapon, "Little Boy", was let loose on the Japanese city of Hiroshima. Three days later, a plutonium-based weapon, "Fat Man", was dropped onto the city of Nagasaki. The atomic bombs killed at least one hundred thousand Japanese outright, most of them civilians, with the heat, radiation, and blast effects. Many tens of thousands would die later of radiation sickness and related cancers. Truman promised a "rain of ruin" if Japan did not surrender immediately, threatening to eliminate Japanese cities, one by one; Japan surrendered on August 15. Truman's threat was in fact a bluff, since the US had not completed more atomic bombs at the time.

Soviet Atomic Bomb Project

(U) The Soviet Union was not invited to share in the new weapons developed by the United States and the other Allies. During the war, information had been pouring in from a number of volunteer spies involved with the Manhattan Project (known in Soviet cables under the code-name of *Enormoz*), and the Soviet nuclear physicist Igor Kurchatov was carefully watching the Allied weapons development. It came as no surprise to Stalin when Truman had informed him at the Potsdam conference that he had a "powerful new weapon." Truman was shocked at Stalin's lack of interest.

The iron hand of NKVD chief Lavrenty Beria was put in charge of the Russian project.

(U) The Soviet spies in the U.S. project were all volunteers and none were Russians. One of the most valuable, Klaus Fuchs, was a German émigré theoretical physicist who had been a part in the early British nuclear efforts and had been part of the UK mission to Los Alamos during the war. Fuchs had been intimately involved in the development of the implosion weapon, and passed on detailed cross-sections of the "Trinity" device to his Soviet contacts. Other Los Alamos spies - none of whom knew each other - included Theodore Hall and David Greenglass. The information was kept but not acted upon, as Russia was still too busy fighting the war in Europe to devote resources to this new project.

(U) In the years immediately after World War II, the issue of who should control atomic weapons became a major international point of contention. Many of the Los Alamos scientists who had built the bomb began to call for "international control of atomic energy", often calling for either control by transnational organizations or the purposeful distribution of weapons information to all superpowers, but due to a deep distrust of the intentions of the Soviet Union, both in postwar Europe and in general, the policy-makers of the United States worked to attempt to secure an American nuclear monopoly. A half-hearted plan for international control was proposed at the newly formed United Nations by Bernard Baruch ("The Baruch Plan"), but it was clear both to American commentators - and to the Soviets - that it was an attempt primarily to stymie Russian nuclear efforts. The Soviets vetoed the plan, effectively ending any immediate postwar negotiations on atomic energy, and made overtures towards banning the use of atomic weapons in general.

(U) All the while, the Soviets had put their full industrial and manpower might into the development of their own atomic weapons. The initial problem for the Soviets was primarily one of resources - they had not scouted out uranium resources in the Soviet Union and the U.S. had made deals to seize monopolies over the largest known reserves in the Belgian Congo. The USSR used penal labour to mine the old deposits in Czechoslovakia - now an area under their control - and searched for other domestic deposits (which were eventually found).

(U) Two days after the bombing of Nagasaki, the U.S. government released an official technical history of the Manhattan Project, authored by Princeton physicist Henry DeWolf Smyth, known colloquially as the Smyth Report. The sanitized summary of the wartime effort focused primarily on the production facilities and scale of investment, written in part to justify the wartime expenditure to the American public. The Soviet program, under the suspicious watch of former NKVD chief Lavrenty Beria (a participant and victor in Stalin's Great Purge of the 1930s), would use the Report as a blueprint, seeking to duplicate as much as possible the American effort. The "secret cities" used for the Soviet equivalents of Hanford and Oak Ridge literally vanished from the maps for decades to come.

The first Soviet bomb, "Joe-1," was tested on August 29, 1949.

(U) At the Soviet equivalent of Los Alamos, Arzamas-16, physicist Yuli Khariton led the scientific effort to develop the weapon. Beria distrusted his scientists, however, and he distrusted the carefully collected espionage information. As such, Beria assigned multiple teams of scientists to the same task without informing each team of the other's existence. If they arrived at different conclusions, Beria would bring them together for the first time and have them debate with their newfound counterparts. Beria used the espionage information as a way to double-check the progress of his scientists, and in his effort for duplication of the American project even rejected more efficient bomb designs in favor of ones which more closely mimicked the tried-and-true "Fat Man" bomb used by the U.S. against Nagasaki.

(U) Working under a stubborn and scientifically ignorant administrator, the Soviet scientists struggled on. On August 29, 1949, the effort brought its results, when the USSR tested its first fission bomb, dubbed "Joe-1" in the U.S., years ahead of American predictions. The news of the first Soviet bomb was announced to the world first by the United States, which had detected the nuclear fallout it generated from its test site in Kazakhstan.

(U) The loss of the American monopoly on nuclear weapons marked the first tit-for-tat of the nuclear arms race. The response in the U.S. was one of apprehension, fear, and scapegoating, which would lead eventually into the Red-baiting tactics of McCarthyism. Before this, though, President Truman would announce his decision to begin a crash program to develop a far more powerful weapon than those which were used against Japan: the hydrogen bomb.

The First Thermonuclear Weapons

(U) The notion of using a fission weapon to ignite a process of nuclear fusion can be dated back to 1942 . At the first major theoretical conference on the development of an atomic bomb hosted by J. Robert Oppenheimer at the University of California, Berkeley, participant Edward Teller directed the majority of the discussion towards Enrico Fermi's idea of a "Super" bomb which would utilize the same reactions which powered the Sun itself. It was thought at the time that a fission weapon would be quite simple to develop and that perhaps work on a hydrogen bomb would be possible to complete before the end of the Second World War. However, in reality the problem of a "regular" atomic bomb was large enough to preoccupy the scientists for the next few years, much less the more speculative "Super." Only Teller continued working on the project - against the will of project leaders Oppenheimer and Hans Bethe.


Hungarian physicist Edward Teller toiled for years trying to discover a way to make a fusion bomb.

(U) After the atomic bombings of Japan, many scientists at Los Alamos rebelled against the notion of creating a weapon thousands of times more powerful than the first atomic bombs. For the scientists the question was in part technical - the weapon design was still quite uncertain and unworkable - and in part moral: such a weapon, they argued, could only be used against large civilian populations, and could thus only be used as a weapon of genocide. Many scientists, such as Bethe, urged that the United States should not develop such weapons and set an example towards the Soviet Union. Promoters of the weapon, including Teller, Ernest Lawrence, and Luis Alvarez, argued that such a development was inevitable, and to deny such protection to the people of the United States - especially when the Soviet Union was likely to create such a weapon themselves - was itself an immoral and unwise act.

(U) Oppenheimer, who was now head of the General Advisory Committee of the successor to the Manhattan Project, the Atomic Energy Commission, presided over a recommendation against the development of the weapon. The reasons were in part because the success of the technology seemed limited at the time (and not worth the investment of resources to confirm whether this was so), and because

Oppenheimer believed that the atomic forces of the United States would be more effective if they consisted of many large fission weapons (of which multiple bombs could be dropped on the same targets) rather than the large and unwieldy predictions of massive super bombs, for which there were a relatively limited amounts of targets of the size to warrant such a development. Furthermore, were such weapons developed by both the U.S. and the USSR, they would be more effectively used against the U.S. than by it, as the U.S. had far more regions of dense industrial and civilian activity which would serve as ideal targets for the large weapons than the Soviet Union did.

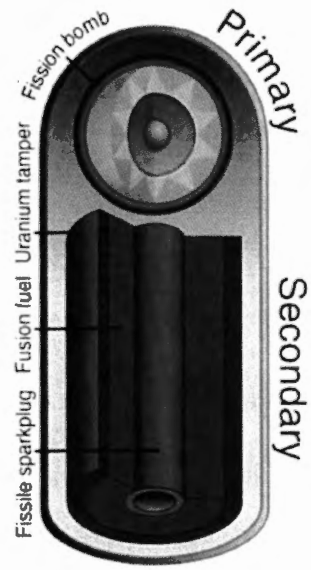
The "Ivy Mike" shot in 1952 inaugurated the age of fusion weapons.

(U) In the end, President Truman made the final decision, looking for a proper response to the first Soviet atomic bomb test in 1949 . On 31 January 1950, Truman announced a crash program to develop the hydrogen (fusion) bomb. At this point, however, the exact mechanism was still not known: the "classical" hydrogen bomb, whereby the *heat* of the fission bomb would be used to ignite the fusion material, seemed highly unworkable. However, an insight by Los Alamos mathematician Stanislaw Ulam showed that the fission bomb and the fusion fuel could be in separate parts of the bomb, and that *radiation* of the fission bomb could first work in a way to *compress* the fusion material before igniting it. Teller pushed the notion further, and used the results of the boosted-fission "George" test (a boosted-fission device using a small amount of fusion fuel to boost the yield of a fission bomb) to confirm the fusion of heavy hydrogen elements before preparing for their first true multi-stage, Teller-Ulam hydrogen bomb test. Many scientists initially against the weapon, such as Oppenheimer and Bethe, changed their previous opinions, seeing the development as being unstoppable. The first fusion bomb was tested by the United States in *Operation Ivy* on 1 November 1952, on Elugelab Island in the Enewetak (or Eniwetok) Atoll of the Marshall Islands, code-named "Mike". "Mike" used liquid deuterium as its fusion fuel and a large fission weapon as its trigger. The device was a prototype design and not a deliverable weapon: standing over 20 ft (6 m) high and weighing at least 140,000 lb (64 t) (its refrigeration equipment added an additional 24,000 lb as well), it could not have been dropped from even the largest planes. Its explosion yielded 10.4 megatons of energy - over 450 times the power of the bomb dropped onto Nagasaki - and obliterated Elugelab, leaving an underwater crater 6240 ft (1.9 km) wide and 164 ft (50 m) deep where the island had once been. Truman had initially tried to create a media blackout about the test - hoping it would not become an issue in the upcoming presidential election - but on January 7, 1953, Truman announced the development of the hydrogen bomb to the world as hints and speculations of it were already beginning to emerge in the press.

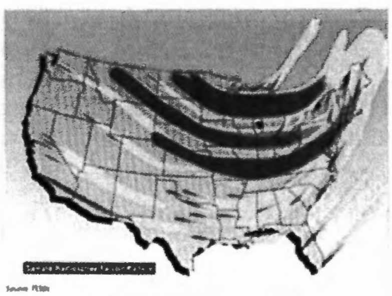
(U) Not to be outdone, the Soviet Union exploded its first thermonuclear device, designed by the physicist Andrei Sakharov, on August 12, 1953, labeled "Joe-4" by the West. This created concern within the U.S. government and military, because, unlike "Mike," the Soviet device was a deliverable weapon, which the U.S. did not yet have. This first device though was arguably not a "true" hydrogen bomb, and could only reach explosive yields in the hundreds of kilotons (never reaching the megaton range of a "staged" weapon). Still, it was a powerful propaganda tool for the Soviet Union, and the technical differences were fairly oblique to the American public and politicians. Following the "Mike" blast by less than a year, "Joe-4" seemed to validate claims that the bombs were inevitable and vindicate those who had supported the development of the fusion program. Coming during the height of McCarthyism, the effect was most pronounced by the security hearings in early 1954 which revoked former Los Alamos director Robert Oppenheimer of his security clearance, on the grounds that he was unreliable, had not supported the American hydrogen bomb program, and had made long-standing, left-wing ties in the 1930s. Edward Teller participated in the hearing as the only major scientist to testify against Oppenheimer, a role which resulted in his virtual expulsion from the physics community.

(U) On 28 February 1954, the U.S. detonated its first deliverable thermonuclear weapon (which used isotopes of lithium as its fusion fuel), known as the "Shrimp" device of the "Castle Bravo" test, at Bikini

Atoll, Marshall Islands. The device yielded 15 megatons of energy, over twice its expected yield, and became the worst radiological disaster in U.S. history. The combination of the unexpectedly large blast and poor weather conditions caused a cloud of radioactive nuclear fallout to contaminate over 7,000 square miles, including Marshall Island natives and the crew of a Japanese fishing boat, as a snow-like mist. The contaminated islands were evacuated (and are still uninhabitable), but the natives received enough of a radioactive dose that they suffered far elevated levels of cancer and birth defects in the years to come. The crew of the Japanese fishing boat, *Fifth Lucky Dragon*, returned to port suffering from radiation sickness and skin burns. Their cargo, many tons of contaminated fish, managed to enter into the market before the cause of their illness was determined. When a crew member died from the sickness and the full results of the contamination were made public by the U.S., Japanese concerns were reignited about the hazards of radiation and resulted in a boycott on eating fish (a main staple of the island country) for some weeks.



(S) The basics of the Teller-Ulam design for a hydrogen bomb: a fusion primary creates a massive number of neutrons to use up much more of the fuel in the fusion secondary. The image reverses the primary and secondary. Therefore it is unclassified.



Fallout from a large nuclear exchange would potentially blanket a country - perhaps even the whole world - with radioactive fission products.

(U) The hydrogen bomb age had a profound effect on the thoughts of nuclear war in the popular and military mind. With only fission bombs, nuclear war could be considered something which could easily be "limited." Dropped by planes and only able to destroy the most built up areas of major cities, it was possible to consider fission bombs simply a technological extension of previous wartime bombing (such as the extensive firebombing which took place against Japan and Germany during World War II), and claims that such weapons could lead to worldwide death or harm were easily brushed aside as grave exaggeration. Even the decades before the development of fission weapons there had been speculation about the possibility for human beings to end all life on the planet by either accident or purposeful maliciousness, but technology had never allowed for such a capacity. The far greater power of hydrogen bombs made this seem ever closer.

(U) The "Castle Bravo" incident itself raised a number of questions about the survivability of a nuclear war. Government scientists in both the U.S. and the USSR had insisted that fusion weapons, unlike fission weapons, were "cleaner" as fusion reactions did not result in the dangerously radioactive by-products as did fission reactions. While technically true, this hid a more gruesome point: the last stage of a multi-staged hydrogen bomb often used the neutrons produced by the fusion reactions to induce fissioning in a jacket of natural uranium, and provided around half of the yield of the device itself. This fission stage made fusion weapons considerably more "dirty" than they were made out to be, a fact made evident by the towering cloud of deadly fallout which followed the "Bravo" test. When the Soviet Union tested its first megatons device in 1955 , the possibility of a limited nuclear war seemed even more remote in the public and political mind: even if a city or country was not the direct target of a nuclear attack, the clouds of fallout and harmful fission products would disperse along with normal weather patterns and embed themselves in the soil and water of non-targeted areas of the planet as well. Speculation began to look towards what would happen as the fallout and dust created by a full-scale nuclear exchange would affect the world as a whole, rather than just the cities and countries which had been directly involved. In this way, the fate of the world was now tied to the fate of the bomb-wielding superpowers.

Deterrence and Brinkmanship

The emergence of nuclear-tipped rockets reflected a change in both nuclear technology and strategy.

(U) Throughout the 1950s and the early 1960s a number of trends were enacted between the U.S. and the USSR as they both endeavored in a tit-for-tat approach to disallow the other power from acquiring nuclear supremacy. This took form in a number of ways, both technologically and politically, and had massive political and cultural effects during the Cold War.

(U) The first atomic bombs dropped on Hiroshima and Nagasaki were large, custom-made devices, requiring highly trained personnel for their arming and deployment. They could be dropped only from the largest bomber planes - at the time the B-29 Superfortress - and each plane could only hold a single bomb in its hold. The first hydrogen bombs were similarly massive and complicated. This ratio of one plane to one bomb was still fairly impressive in comparison with conventional, non-nuclear weapons, but against other nuclear-armed countries it was considered to be a grave danger. In the immediate postwar years, the U.S. expended much effort on making the bombs "G.I.-proof" - capable of being used and deployed by members of the U.S. Army, rather than Nobel Prize--winning scientists, and in the 1950s a program of nuclear testing was undertaken in order to improve the nuclear arsenal.

(U) Starting in 1951 , the Nevada Test Site (in the Nevada desert) became the primary location for all U.S. nuclear testing (in the USSR, Semipalatinsk Test Site in Kazakhstan served a similar role). Tests were divided into two primary categories: "weapons related" (verifying that a new weapon worked or looking at exactly how it worked) and "weapons effects" (looking at how weapons behaved under various conditions or how structures behaved when subjected to weapons). In the beginning, almost all nuclear tests were either "atmospheric" (conducted above ground, in the atmosphere) or "underwater" (such as some of the tests done in the Marshall Islands). Testing was used as a sign of both national and technological strength, but also raised questions about the safety of the tests, which released nuclear fallout into the atmosphere (most dramatically with the Castle Bravo test in 1954 , but in more limited amounts with almost all atmospheric nuclear testing).

Hundreds of nuclear tests were conducted at the Nevada Test Site in the USA.

(U) Because testing was seen as a sign of technological development (the ability to design usable weapons without some form of testing was considered dubious), halts on testing were often called for as stand-ins for halts in the nuclear arms race itself, and many prominent scientists and statesmen lobbied for a ban on nuclear testing. In 1958 , the U.S., USSR, and the United Kingdom (a new nuclear power) declared a temporary testing moratorium for both political and health reasons, but by 1961 the Soviet Union had broken the moratorium and both the USSR and the U.S. began testing with great frequency. As a show of political strength, the Soviet Union tested the largest-ever nuclear weapon in October 1961, the massive Tsar Bomba, which was tested in a reduced state with a yield of around 50 megatons - in its full state it was estimated to have been around 100 Mt. The weapon was largely impractical for actual military use, but was hot enough to induce third-degree burns at a distance of 62 mi (100 km) away. In its full, "dirty" design, it would have increased the amount of worldwide fallout since 1945 by 25%.

(U) In 1963, all nuclear and many non-nuclear states signed the Limited Test Ban Treaty, pledging to refrain from testing nuclear weapons in the atmosphere, underwater, or in outer space. The treaty permitted underground tests.

(U) Most tests were considerably more modest, and worked for direct technical purposes as well as their potential political overtones. Weapons improvements took on two primary forms. One was an increase in efficiency and power, and within only a few years fission bombs were being developed which were many times more powerful than the ones created during World War II. The other was a program of miniaturization, reducing the size of the nuclear weapons themselves. Smaller bombs meant that bombers could carry more of them, and thus become even more of a threat against even the most rigorous air defenses, and they could also be used in conjunction with the development in rocketry during the 1950s and 1960s. U.S. rocket efforts had received a large boost in the postwar years, largely from the acquiring of engineers who had worked on the Nazi rocketry program during the war, such as Wernher von Braun, who had been involved in the design and manufacture of the V-2 rockets which were launched across the English Channel. An American program, Project Paperclip, had endeavored to move scientists of this sort into American hands (and kept out of Soviet hands) and put them to work on projects for the U.S.

Weapons Improvement

(U) The first nuclear-tipped rockets, such as the MGR-1 Honest John, first deployed by the U.S. in 1953 , were surface-to-surface missiles with relatively short ranges (around 15 mi/25 km maximum) with yields around twice the size of the first fission weapons. The limited range of these weapons meant that they could only be used in certain types of potential military situations - the U.S. rocket weapons could not, for example, threaten the city of Moscow with the threat of an immediate strike, and could only be used as "tactical" weapons (that is, for small-scale military situations).

(U) For "strategic" weapons - weapons which would serve to threaten an entire country - for the time being, only long-range bombers capable of penetrating deep into enemy territory would work. In the U.S. this resulted in the creation of the Strategic Air Command in 1946 , a system of bombers headed by General Curtis LeMay (who had previously presided over the firebombing of Japan during WWII), which kept a number of nuclear-armed planes in the sky at all times, ready to receive orders to attack Moscow whenever commanded.

Long-range bomber aircraft, such as the B-52 Stratofortress, allowed for a wide range of "strategic" nuclear forces to be deployed.

(U) These technological possibilities enabled nuclear strategy to develop a logic considerably different than previous military thinking had allowed. Because the threat of nuclear warfare was so awful, it was first thought that it might make any war of the future impossible. Eisenhower's doctrine of "massive retaliation" in the early years of the Cold War was a message to the USSR, saying that if the Red Army attempted to invade the parts of Europe not given to the Eastern bloc during the Potsdam Conference (such as West Germany), nuclear weapons would be used against the Soviet troops and potentially the Soviet leaders.

(U) With the development of more rapid-response technologies (such as rockets and long-range bombers), this policy began to shift. If the Soviet Union also had nuclear weapons and a policy of "massive retaliation" was carried out, it was reasoned, then any Soviet forces not killed in the initial attack, or launched while the attack was ongoing, would be able to serve their own form of nuclear "retaliation" against the U.S. Recognizing this to be an undesirable outcome, military officers and game theorists at the RAND think tank developed a nuclear warfare strategy that would eventually become known as Mutually Assured Destruction (MAD).

(U) MAD divided potential nuclear war into two stages: first strike and second strike. A first strike would be the first use of nuclear weapons by one nuclear-equipped nation against another nuclear-equipped nation. If the attacking nation did not prevent the attacked nation from a nuclear response, then a second strike could be deployed against the attacking nation. In this situation, whether the U.S. first attacked the

Submarine launched ballistic missiles made defending against nuclear war an impossibility.

USSR or the USSR first attacked the U.S., the end result would be that both nations would be damaged perhaps to the point of utter social collapse. According to game theory, because starting a nuclear war would be suicidal, no logical country would willfully enter into a nuclear war. However, if a country were capable of launching a first strike which would utterly destroy the ability of the attacked country to respond in kind, then the balance of power would be disturbed and nuclear war could then be safely undertaken.

(U) MAD played on two seemingly opposed modes of thought: cold logic and emotional fear. The phrase by which MAD was often known, "nuclear deterrence", was translated as "dissuasion" by the French and "terrorization" by the Russians. This apparent paradox of nuclear war was summed up by British Prime Minister Winston Churchill as "the worse things get, the better they are" - the greater the threat of mutual destruction, the safer the world would be.

With early warning systems, it was thought that the strikes of nuclear war would come from dark rooms filled with computers, not the battlefield of the wars of old.

(U) This philosophy made a number of technological and political demands on participating nations. For one thing, it said that it should always be assumed that an enemy nation may be trying to acquire "first strike capability," something which must always be avoided. In American politics this translated into demands to avoid "missile gaps" and "bomber gaps" where the Soviet Union could potentially "out shoot" American efforts (most of these supposed "gaps" proved to be political figments, but this hardly mattered at the time). It also encouraged the production of thousands of nuclear weapons by both the U.S. and the USSR, far more than would be needed to simply destroy the major civilian and military infrastructures of the opposing country.

(U) The policy also encouraged the development of the first early warning systems. Conventional war, even at its fastest, was fought over time scales of days and weeks. With long-range bombers, the time from the start of an attack to its conclusion was reduced to mere hours. With rockets, it could be reduced to minutes. It was reasoned that conventional command and control systems could not be expected to adequately respond to a nuclear attack, and so great lengths were taken to develop the first computers which could look for enemy attacks and direct rapid responses. In the U.S., massive funding was poured into the development of Semi Automatic Ground Environment (SAGE), a system which would track and intercept enemy bomber aircraft using information from remote radar stations, and was the first computer system to feature real-time processing, multiplexing, and display devices - the first "general" computing machine, and a direct predecessor of modern computers.

Anti-Nuclear

(U) Bombers and short-range rockets were not reliable: planes could be shot down, and earlier nuclear missiles could cover only a limited range - for example, the first Soviet rockets' range limited them to targets in Europe. However, by the 1960s, both the United States and the Soviet Union had developed intercontinental ballistic missiles, which could be launched from extremely remote areas far away from their target; and submarine-launched ballistic missiles, which had less range but could be launched from submarines very close to the target without any radar warning. This made any national protection from nuclear missiles increasingly impractical.

(U) The military realities made for a precarious diplomatic situation. The international politics of brinkmanship led leaders to exclaim their willingness to participate in a nuclear war rather than concede any advantage to their opponents, feeding public fears that their generation may be the last. Civil defense programs undertaken by both superpowers, exemplified by the construction of fallout shelters and urging civilians about the "survivability" of nuclear war, did little to ease public concerns. A joke known by most Russians during the Cold War said that when one heard the air raid sirens, one should pick up a shovel and quietly proceed to the nearest cemetery, to dig your own grave. A similar joke in the U.S. recommended that one stay calm, put one's head between one's legs, and kiss your ass goodbye, a parody of the "duck and cover" routines practiced by schoolchildren across the country.

U-2 photographs revealed that the Soviet Union was stationing nuclear missiles on the island of Cuba in 1962 , beginning the Cuban Missile Crisis.

(U) The climax of brinksmanship came in early 1962 , when an American U-2 spy plane photographed a series of launch sites for medium-range ballistic missiles being constructed on the island of Cuba, just off the coast of the southern United States, beginning what became known as the Cuban Missile Crisis. The U.S. administration of John F. Kennedy concluded that the Soviet Union, then led by Nikita Khrushchev, was planning to station Russian nuclear missiles on the island, which was under the control of Communist Fidel Castro. On October 22, Kennedy announced the discoveries in a televised address, and declared that a naval quarantine would be put around Cuba to turn back any Soviet nuclear shipments, and warned that the military was prepared "for any eventualities." The missiles would have a range of 2,400 miles (4,000 km), and allow the Soviet Union to easily destroy many major American cities on the Eastern Seaboard if a nuclear war were started.

(U) The leaders of the two superpowers stood nose to nose, seemingly poised over the beginnings of a third world war. Khrushchev's ambitions for putting the weapons on the island were motivated in part by the fact that the U.S. had stationed similar weapons in Britain, Italy, and nearby Turkey, and had previously attempted to sponsor an invasion of Cuba the year before in the failed Bay of Pigs Invasion. On October 26, an offer was sent from Khrushchev to Kennedy offering to withdraw all missiles if Kennedy would commit to a policy of no future invasions of Cuba. Khrushchev worded the threat of assured destruction eloquently:

> "You and I should not now pull on the ends of the rope in which you have tied a knot of war, because the harder you and I pull, the tighter the knot will become. And a time may come when this knot is tied so tight that the person who tied it is no longer capable of untying it, and then the knot will have to be cut. What that would mean I need not explain to you, because you yourself understand perfectly what dreaded forces our two countries possess."

(U) A day later, however, the Russians put forward another offer, this time demanding that the U.S. remove its missiles from Turkey before any missiles would be withdrawn from Cuba. On the same day, a U-2 plane was shot down over Cuba and another was almost intercepted over Russia, and Soviet merchant ships were nearing the quarantine zone. Kennedy responded by accepting the first deal publicly, and sending his brother Robert to the Soviet embassy to accept the second deal in private. On October 28, the Soviet ships stopped at the quarantine line and, after some hesitation, turned back towards the Soviet Union. Khrushchev announced that he had ordered the removal of all missiles in Cuba, and U.S. Secretary of State Dean Rusk was moved to comment, "We went eyeball to eyeball, and the other fellow just blinked."

(U) The Crisis was later seen as the closest the U.S. and the USSR ever came to nuclear war and had been narrowly averted by last-minute compromise by both superpowers. Fears of communication difficulties led to the installment of the first hotline, a direct link between the superpowers which would allow them to more easily discuss future military activities and political maneuverings. It had been made clear that with their missiles, bombers, submarines, and computerized firing systems, the escalation of any situation to Armageddon could be done far easier than anybody desired.

(U) After stepping so close to the brink, both the U.S. and the USSR worked to reduce their nuclear tensions in the years immediately following. The most immediate culmination of this work was the signing of the Partial Test Ban Treaty in 1963 , in which the U.S. and USSR agreed to no longer test nuclear weapons in the atmosphere, underwater, or in outer space. Testing underground continued, allowing for further weapons development, but the worldwide fallout risks were purposefully reduced, and the era of using massive nuclear tests as a form of saber-rattling had primarily ended.

Nikita Khrushchev urged John F. Kennedy not to cut the "knot of war" created by nuclear deterrence.

(U) In 1981, as U.S. President Ronald Reagan's administration pushed the arms race to new levels of higher tension with the USSR, one million people marched for nuclear disarmament and abolition in New York City. As the nuclear abolitionist movement grew, over 2,000 people were arrested in a two-day period in 1988 at the gate of the Nevada Test Site. Four of the significant groups organizing this renewal of anti-nuclear activism were Greenpeace, The American Peace Test, The Western Shoshone, and Nevada Desert Experience. Nevada Desert Experience (NDE) had kickstarted the renewal in 1982, and maintained annual resistance and prayer-actions for peace in Western Shoshone country (within Nevada) for 25 years.

Initial Proliferation

(U) In the fifties and sixties, three more countries joined the "nuclear club."

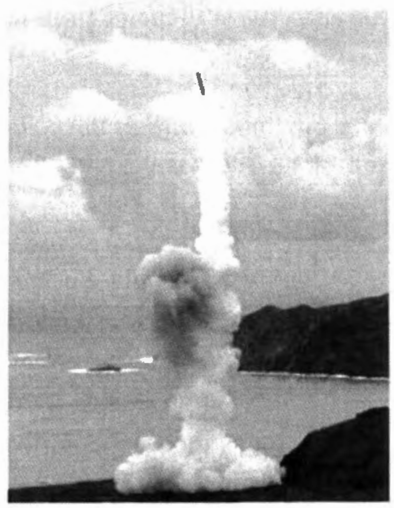
(U) The United Kingdom had been an integral part of the Manhattan Project following the Quebec Agreement in 1943 . The passing of the McMahon Act by the United States in 1946 unilaterally broke this partnership and prevented the passage of any further information to the United Kingdom. The British Government under Clement Attlee determined that it would be essential for there to be a British Bomb. Because of the involvement in the Manhattan Project Britain had extensive knowledge in some areas, but not in others. An improved version of 'Fat Man' was developed, and on 26 February 1952, Prime Minister Winston Churchill announced that the United Kingdom also had an atomic bomb and a successful test took place on the 3 October 1952. At first these were free-fall bombs and then there was a missile, Blue Steel, and a later-canceled medium-range ballistic missile, Blue Streak. Anglo-American cooperation on Nuclear weapons was restored by the 1958 US-UK Mutual Defence Agreement. As a result of this and the Polaris Sales Agreement, the United Kingdom has bought United States designs for submarine missiles and fitted its own warheads. It retains full independent control over the use of the missiles. It no longer possesses any free-fall bombs.

(U) France had been heavily involved in nuclear research before World War II through the work of the Joliot-Curies. This was discontinued after the war because of the instability of the Fourth Republic and the lack of finance available.[1] However, in the 1950's a civil nuclear research program was started, a byproduct of which would be plutonium. In 1956 a secret Committee for the Military Applications of Atomic Energy was formed and a development program for delivery vehicles started. With the return of Charles de Gaulle to the presidency of France in 1958 the final decisions to build a bomb were taken, and a successful test took place in 1960 . Since then France has developed and maintained its own nuclear deterrent.

(U) In 1951 China and the Soviet Union signed an agreement whereby China would supply uranium ore in exchange for technical assistance in producing nuclear weapons. In 1953 China had established a research program under the guise of civilian nuclear energy. Throughout the 1950's the Soviet Union provided large amounts of equipment, but as the relations between the two countries worsened, the amount of assistance was reduced, and in 1959 the donation of a bomb for copying purposes was refused. Despite this, rapid progress was made with the test of an atomic bomb on the 16th October 1964 at Lop Nur, a nuclear missile on 25th October 1966, and of a hydrogen bomb on the 14th June 1967. Nuclear warheads were produced from 1968 and thermonuclear warheads from 1974 . The Cultural Revolution slowed the pace of progress, but it is thought that tactical nuclear weapons have been developed. It is also thought that Chinese warheads have been successfully miniaturised from 2200kg to 700kg through the use of designs obtained by espionage from the United States. The current number of weapons is unknown owing to strict secrecy, but it is thought that up to 2000 warheads may have been produced, though far fewer may be available for use. China is the only one of the Nuclear Weapons States to have guaranteed the non-first use of nuclear weapons.

Cold War

(U) After World War II, the balance of power between the Eastern and Western blocs, resulting in the fear of global destruction, prevented the further military use of atomic bombs. This fear was even a central part of Cold War strategy, referred to as the doctrine of Mutually Assured Destruction ("MAD" for short). So important was this balance to international political stability that a treaty, the Anti-Ballistic Missile Treaty (or ABM treaty), was signed by the U.S. and the USSR in 1972 to curtail the development of defenses against nuclear weapons and the ballistic missiles which carry them. This doctrine resulted in a large increase in the number of nuclear weapons, as each side sought to ensure it possessed the firepower to destroy the opposition in all possible scenarios and against all perceived threats.



ICBMs, like the American Minuteman missile, allowed nations to deliver nuclear weapons thousands of miles away with relative ease.

(U) Early delivery systems for nuclear devices were primarily bombers like the United States B-29 Superfortress and Convair B-36, and later the B-52 Stratofortress. Ballistic missile systems, based on Wernher von Braun's World War II designs (specifically the V2 rocket), were developed by both United States and Soviet Union teams (in the case of the U.S., effort was directed by the German scientists and engineers). These systems, after testing, were used to launch satellites, such as Sputnik, and to propel the Space Race, but they were primarily developed to create the capability of Intercontinental Ballistic Missiles (ICBMs) with which nuclear powers could deliver that destructive force anywhere on the globe. These systems continued to be developed throughout the Cold War, although plans and treaties, beginning with the Strategic Arms Limitation Treaty (SALT I), restricted deployment of these systems until, after the fall of the Soviet Union, system development essentially halted, and many weapons were disabled and destroyed.

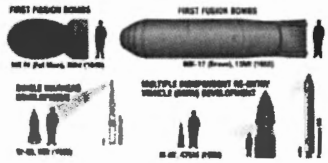
(U) There have been a number of potential nuclear disasters. Following air accidents U.S. nuclear weapons have been lost near Atlantic City, New Jersey (1957); Savannah, Georgia (1958) (see Tybee Bomb); Goldsboro, North Carolina (1961); off the coast of Okinawa (1965); in the sea near Palomares, Spain (1966); and near Thule, Greenland (1968). Most of the lost weapons were recovered, the Spanish device after three months' effort by the DSV Alvin and DSV Aluminaut. The Soviet Union was less forthcoming about such incidents, but the environmental group Greenpeace believes that there are around forty non-U.S. nuclear devices that have been lost and not recovered, compared to eleven lost by America, mostly in submarine disasters. The U.S. has tried to recover Soviet devices, notably in the 1974 Operation

Jennifer using the specialist salvage vessel *Hughes Glomar Explorer*.

(U) On 27 January 1967, more than 60 nations signed the Outer Space Treaty, banning nuclear weapons in space.

(U) The end of the Cold War failed to end the threat of nuclear weapon use, although global fears of nuclear war reduced substantially.

(U) In a major move of de-escalation, Boris Yeltsin, on January 26, 1992, announced that Russia planned to stop targeting United States cities with nuclear weapons.



Relative sizes of a number of nuclear weapons.

Further Nuclear Proliferation

(U) India's first atomic-test explosion was in 1974 with Smiling Buddha, which it described as a "peaceful nuclear explosion". India tested fission and perhaps fusion devices in 1998 , and Pakistan successfully tested fission devices that same year, raising concerns that they would use nuclear weapons on each other. All of the former Soviet bloc countries with nuclear weapons (Belarus, Ukraine, and Kazakhstan) returned their warheads to Russia by 1996 , though recent data has suggested that a clerical error may have left some warheads in Ukraine.

(U) In January 2004 , Pakistani metallurgist and weapons scientist Abdul Qadeer Khan confessed to having been a part of an international proliferation network of materials, knowledge, and machines from Pakistan to Libya, Iran, and North Korea.

~~(S)~~ South Africa also had an active program to develop uranium-based nuclear weapons, but dismantled its nuclear weapon program in the 1990s. It is not believed that it actually tested such a weapon though it later claimed to have constructed several crude devices which it eventually dismantled. In the late 1970s American spy satellites detected a "brief, intense, double flash of light near the southern tip of Africa." [2] which was speculated to have been a South African nuclear weapons test, though a later scientific review of the data indicated that it may have been caused by natural events. However, the data from the Vela satellite's Bhangmeter is conclusive proof that Alert 747 was a nuclear test. Conclusive nuclear material was also observed in Australia.

~~(S)~~ Israel is widely believed to possess an arsenal of potentially up to several hundred nuclear warheads, but this has never been officially confirmed or denied (though the existence of their Dimona nuclear facility was more or less confirmed by the leaks of the dissident Mordechai Vanunu in 1986). The Israelis worked with South Africa on Alert 747.

~~(S)~~ North Korea announced in 2003 that it also had several nuclear explosives though it has not been confirmed and the validity of this has been a subject of scrutiny amongst weapons experts. The first detonation of a nuclear weapon by the Democratic People's Republic of Korea was the 2006 North Korean nuclear test, conducted on 9 October 2006. They also conducted a test again in May 2009. Intelligence indicators suspected that they would test again in 2012. However, no such test has occurred.

(U) In Iran, Ayatollah Ali Khamenei issued a fatwa forbidding the production, stockpiling and use of nuclear weapons on 9 August 2005. The full text of the fatwa was released in an official statement at the meeting of the International Atomic Energy Agency (IAEA) in Vienna.[3] Despite this, however, there is mounting concern in many nations about Iran's refusal to halt its nuclear power program, which many fear is a cover for weapons development.

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Nuclear Weapons				
Arms Race	Delivery	Explosion Effects	**History**	Proliferation
Testing	Tests	Warfare	Weapons	
Weapon Design				
Teller-Ulam (Fusion)	Gun Type (Fission)	Implosion Type (Fission)	ICBM/SLBM	MIRV

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(U) History of Nuclear Weapons

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From Intellipedia

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The **history of nuclear weapons** chronicles the development of nuclear weapons - devices of enormous destructive potential which derive their energy from nuclear fission or nuclear fusion reactions - starting with the scientific breakthroughs of the 1930s which made their development possible, continuing through the nuclear arms race and nuclear testing of the Cold War, and finally with the questions of proliferation and possible use for terrorism in the early 21st century.

A nuclear fireball lights up the night in a United States nuclear test.

Contents

Introduction

The first fission weapons ("atomic bombs") were developed in the United States during World War II in what was called the Manhattan Project, at which point two were dropped on Japan. The Soviet Union started development shortly thereafter with their own atomic bomb project, and not long after that both

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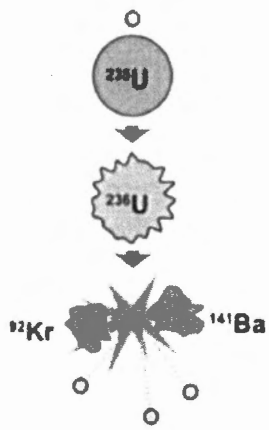
countries developed even more powerful fusion weapons ("hydrogen bombs"). During the Cold War, these two countries each acquired nuclear weapons arsenals numbering in the thousands, placing many of them onto rockets which could hit targets anywhere in the world. Currently there are at least nine countries with functional nuclear weapons. A considerable amount of international negotiating has focused on the threat of nuclear warfare and the proliferation of nuclear weapons to new nations or groups. There have been (at least) four major false alarms, the most recent in 1995, that almost resulted in the US or Russia launching its weapons in retaliation for a supposed attack.

Physics and Politics in the 1930s



In nuclear fission, the nucleus of a fissile atom (in this case, enriched uranium) absorbs a thermal neutron, becomes unstable, and splits into two new atoms, releasing some energy and between one and three new neutrons, which can perpetuate the process.

In the first decades of the twentieth century, physics was revolutionized with developments in the understanding of the nature of atoms. In 1898 , French physicist Pierre Curie and his Polish wife Marie had discovered that present in pitchblende, an ore of uranium, was a substance which emitted large amounts of radioactivity, which they named radium. This raised the hopes of both scientists and lay people that the elements around us could contain tremendous amounts of unseen energy, waiting to be tapped.

Experiments by Ernest Rutherford in 1911 indicated that the vast majority of an atom's mass was contained in a very small nucleus at its core, made up of protons, surrounded by a web of whirring electrons. In 1932, James Chadwick discovered that the nucleus contained another fundamental particle, the neutron, and in the same year John Cockcroft and Ernest Walton "split the atom" for the first time, the first occasion on which an atomic nucleus of one element had been successfully changed to a different nucleus by artificial means.

In 1934 , French physicists Irène and Frédéric Joliot-Curie discovered that artificial radioactivity could be induced in stable elements by bombarding them with alpha particles, and in the same year Italian physicist Enrico Fermi reported similar results when bombarding uranium with neutrons.

In 1938 , Germans Otto Hahn and Fritz Strassmann released the results of their finding proving that what Fermi had witnessed in 1934 was no less than the bursting of the uranium nucleus: nuclear fission. Immediately afterwards, Lise Meitner and Otto Robert Frisch described the theoretical mechanisms of fission and revealed that large amounts of binding energy were released in the process. Hungarian Leó Szilárd confirmed with his own experiments that along with energy, neutrons were given off in the reaction as well, creating the possibility of a nuclear chain reaction, whereby each fission created two or more other fissions, exponentially releasing energy.

As the Nazi army marched into first Czechoslovakia in 1938, and then Poland in 1939 , officially beginning World War II, many of Europe's top physicists had already begun to flee from the imminent conflict. Scientists on both sides of the conflict were well aware of the possibility of utilizing nuclear fission as a weapon, but at the time no one was quite sure how it could be done. In the early years of the Second World War, physicists abruptly stopped publishing on the topic of fission, an act of self-censorship

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to keep the opposing side from gaining any advantages.

From Los Alamos to Hiroshima


UC Berkeley physicist J. Robert Oppenheimer led the Allied scientific effort at Los Alamos National Laboratory.

By the beginning of World War II, there was concern among scientists in the Allied nations that Nazi Germany might have their own project to develop fission-based weapons. Organized research first began in Britain as part of the "Tube Alloys" project, and in the United States a small amount of funding was given for research into uranium weapons starting in 1939 with the Uranium Committee under Lyman James Briggs. At the urging of British scientists, though, who had made crucial calculations indicating that a fission weapon could be completed within only a few years, by 1941 the project had been wrested into better bureaucratic hands, and in 1942 came under the auspices of General Leslie Groves as the Manhattan Project. Scientifically led by the American physicist Robert Oppenheimer, the project brought together the top scientific minds of the day (many exiles from Europe) with the production power of American industry for the goal of producing fission-based explosive devices before Germany could. Britain and the U.S. agreed to pool their resources and information for the project, but the other Allied power - the Soviet Union under Joseph Stalin - was not informed. A massive industrial and scientific undertaking, the Manhattan Project involved many of the world's great physicists in the scientific and development aspects. The United States made an unprecedented investment into wartime research for the project, which was spread across over 30 sites in the U.S. and Canada. Scientific knowledge was centralized at a secret laboratory known as Los Alamos, previously a small ranch school near Santa Fe, New Mexico. Uranium appears in nature primarily in two isotopes: uranium-238 and uranium-235. When the nucleus of uranium-235 absorbs a neutron, it undergoes nuclear fission, splitting into two "fission products" and releasing energy and 2.5 neutrons on average. Uranium-238, on the other hand, absorbs neutrons and does not fission, effectively putting a stop to any ongoing fission reaction. It was discovered that an atomic bomb based on uranium would need to be made of almost completely pure uranium-235 (at least 80% pure), or else the presence of uranium-238 would quickly curtail the nuclear chain reaction. The team of scientists working on the Manhattan Project immediately realized that one of the largest problems they would have to solve was how to remove uranium-235 from natural uranium, which was composed of 99.3% uranium-238. Two methods were developed during the wartime project, both of which took advantage of the fact that uranium-238 has a slightly greater atomic mass than uranium-235: electromagnetic separation and gaseous diffusion - methods which separated isotopes based on their differing weights. Another secret site was erected at rural Oak Ridge, Tennessee, for the large-scale production and purification of the rare isotope. It was a massive investment: at the time, one of the Oak Ridge facilities (K-25) was the largest factory under one roof. The Oak Ridge site employed tens of thousands of employees at its peak, most of whom had no idea what they were working on.

Though uranium-238 cannot be used inside an atomic bomb, when it absorbs a neutron it transforms first into an unstable element, uranium-239, and then decays into neptunium-239 and finally the relatively stable plutonium-239, an element which does not exist in nature. Plutonium is also fissile and can be used to create a fission reaction, and after Enrico Fermi achieved the world's first sustained and controlled

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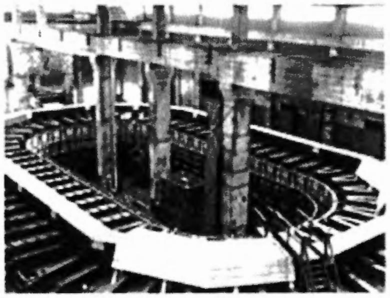
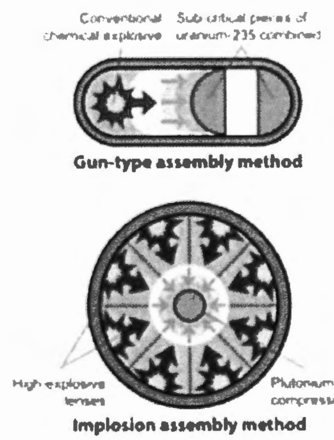


Massive new physics machines were assembled at secret installations around the United States for the production of enriched uranium and plutonium.

nuclear chain reaction in the creation of the first "atomic pile" - a primitive nuclear reactor - in a basement at the University of Chicago, massive reactors were secretly created at what is now known as Hanford Site in the state of Washington, using the Columbia River as cooling water, to transform uranium-238 into plutonium for a bomb. For a fission weapon to operate, there must be a critical mass - the amount needed for a self-sustaining nuclear chain reaction - of fissile material bombarded with neutrons at any one time. The simplest form of nuclear weapon would be a gun-type fission weapon, where a sub-critical mass of fissile material (such as uranium-235) would be shot at another sub-critical mass of fissile material. The result would be a super-critical mass which, when bombarded with neutrons, would undergo fission at a rapid rate and create the desired explosion.



The two fission bomb assembly methods.

But it was soon discovered that plutonium cannot be used in a "gun assembly," as it has too high a level of background neutron radiation; it undergoes spontaneous fission to a very small extent. If plutonium were used in a "gun assembly," the chain reaction would start in the split seconds before the critical mass was assembled, blowing the weapon apart before it would have any great effect (this is known as a fizzle). After some despair, Los Alamos scientists discovered another approach: using chemical explosives to implode a sub-critical sphere of plutonium, which would increase its density and make it into a critical mass. The difficulties with implosion were in the problem of making the chemical explosives deliver a perfectly uniform shock wave upon the plutonium sphere - if it were even slightly asymmetric, the weapon would fizzle (which would be expensive, messy, and not a very effective military device). This problem was circumvented by the use of hydrodynamic "lenses" - explosive materials of differing densities - which would focus the blast waves inside the imploding sphere, akin to the way in which an optical lens focuses light rays.

After D-Day, General Groves had ordered a team of scientists - Project Alsos - to follow eastward-moving victorious Allied troops into Europe in order to assess the status of the German nuclear program (and to prevent the westward-moving Russians from gaining any materials or scientific manpower). It was concluded that while Nazi Germany had also had an atomic bomb program, headed by Werner Heisenberg, the government had not made a significant investment in the project, and had been nowhere near success.

By the unconditional surrender of Germany on 8 May 1945, the Manhattan Project was still months away from a working weapon. That April, after the death of American President Franklin D. Roosevelt, former Vice-President Harry S. Truman was told about the secret wartime project for the first time.

Because of the difficulties in making a working plutonium bomb, it was decided that there should be a test of the weapon, and Truman wanted to know for sure if it would work before his meeting with Joseph Stalin at an upcoming conference on the future of postwar Europe. On July 16, 1945, in the desert north of Alamogordo, New Mexico, the first nuclear test took place, code-named "Trinity," using a device nicknamed "the Gadget." The test released the equivalent of 19 kilotons of TNT, far mightier than any weapon ever used before. The news of the test's success was rushed to Truman, who used it as leverage at

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the upcoming Potsdam Conference, held near Berlin.


The atomic fireball at the "Trinity" nuclear test secretly rang in the atomic age.


The atomic bombings of Hiroshima and Nagasaki killed tens of thousands of Japanese civilians.

After hearing arguments from scientists and military officers over the possible uses of the weapons against Japan (though some recommended using them as "demonstrations" in unpopulated areas, most recommended using them against "built up" targets, a euphemistic term for populated cities), Truman ordered the use of the weapons on Japanese cities, hoping it would send a strong message which would end in the capitulation of the Japanese leadership and avoid a lengthy invasion of the island. There were suggestions to drop the atomic bomb on Tokyo, the capital of Japan, but concerns about Tokyo's cultural heritage changed the plan. On 6 August 1945, a uranium-based weapon, "Little Boy", was let loose on the Japanese city of Hiroshima. Three days later, a plutonium-based weapon, "Fat Man", was dropped onto the city of Nagasaki. The atomic bombs killed at least one hundred thousand Japanese outright, most of them civilians, with the heat, radiation, and blast effects. Many tens of thousands would die later of radiation sickness and related cancers. Truman promised a "rain of ruin" if Japan did not surrender immediately, threatening to eliminate Japanese cities, one by one; Japan surrendered on August 15. Truman's threat was in fact a bluff, since the US had not completed more atomic bombs at the time.

Soviet Atomic Bomb Project

The Soviet Union was not invited to share in the new weapons developed by the United States and the other Allies. During the war, information had been pouring in from a number of volunteer spies involved with the Manhattan Project (known in Soviet cables under the code-name of *Enormoz*), and the Soviet nuclear physicist Igor Kurchatov was carefully watching the Allied weapons development. It came as no surprise to Stalin when Truman had informed him at the Potsdam conference that he had a "powerful new weapon." Truman was shocked at Stalin's lack of interest.

The Soviet spies in the U.S. project were all volunteers and none were Russians. One of the most valuable, Klaus Fuchs, was a German émigré theoretical physicist who had been a part in the early British nuclear efforts and had been part of the UK mission to Los Alamos during the war. Fuchs had been intimately involved in the development of the implosion weapon, and passed on detailed cross-sections of the "Trinity" device to his Soviet contacts. Other Los Alamos spies - none of whom knew each other - included Theodore Hall and David Greenglass. The information was kept but not acted upon, as Russia was still too busy fighting the war in Europe to devote resources to this new project.

In the years immediately after World War II, the issue of who should control atomic weapons became a major international point of contention. Many of the Los Alamos scientists who had built the bomb began to call for "international control of atomic energy", often calling for either control by transnational organizations or the purposeful distribution of weapons information to all superpowers, but due to a deep

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distrust of the intentions of the Soviet Union, both in postwar Europe and in general, the policy-makers of the United States worked to attempt to secure an American nuclear monopoly. A half-hearted plan for international control was proposed at the newly formed United Nations by Bernard Baruch ("The Baruch Plan"), but it was clear both to American commentators - and to the Soviets - that it was an attempt primarily to stymie Russian nuclear efforts. The Soviets vetoed the plan, effectively ending any immediate postwar negotiations on atomic energy, and made overtures towards banning the use of atomic weapons in general.

The iron hand of NKVD chief Lavrenty Beria was put in charge of the Russian project.

All the while, the Soviets had put their full industrial and manpower might into the development of their own atomic weapons. The initial problem for the Soviets was primarily one of resources - they had not scouted out uranium resources in the Soviet Union and the U.S. had made deals to seize monopolies over the largest known reserves in the Belgian Congo. The USSR used penal labour to mine the old deposits in Czechoslovakia - now an area under their control - and searched for other domestic deposits (which were eventually found).

Two days after the bombing of Nagasaki, the U.S. government released an official technical history of the Manhattan Project, authored by Princeton physicist Henry DeWolf Smyth, known colloquially as the Smyth Report. The sanitized summary of the wartime effort focused primarily on the production facilities and scale of investment, written in part to justify the wartime expenditure to the American public. The Soviet program, under the suspicious watch of former NKVD chief Lavrenty Beria (a participant and victor in Stalin's Great Purge of the 1930s), would use the Report as a blueprint, seeking to duplicate as much as possible the American effort. The "secret cities" used for the Soviet equivalents of Hanford and Oak Ridge literally vanished from the maps for decades to come.

The first Soviet bomb, "Joe-1," was tested on August 29, 1949.

At the Soviet equivalent of Los Alamos, Arzamas-16, physicist Yuli Khariton led the scientific effort to develop the weapon. Beria distrusted his scientists, however, and he distrusted the carefully collected espionage information. As such, Beria assigned multiple teams of scientists to the same task without informing each team of the other's existence. If they arrived at different conclusions, Beria would bring them together for the first time and have them debate with their newfound counterparts. Beria used the espionage information as a way to double-check the progress of his scientists, and in his effort for duplication of the American project even rejected more efficient bomb designs in favor of ones which more closely mimicked the tried-and-true "Fat Man" bomb used by the U.S. against Nagasaki.

Working under a stubborn and scientifically ignorant administrator, the Soviet scientists struggled on. On August 29, 1949, the effort brought its results, when the USSR tested its first fission bomb, dubbed "Joe-1" in the U.S., years ahead of American predictions. The news of the first Soviet bomb was announced to the world first by the United States, which had detected the nuclear fallout it generated from its test site in Kazakhstan.

The loss of the American monopoly on nuclear weapons marked the first tit-for-tat of the nuclear arms race. The response in the U.S. was one of apprehension, fear, and scapegoating, which would lead eventually into the Red-baiting tactics of McCarthyism. Before this, though, President Truman would announce his decision to begin a crash program to develop a far more powerful weapon than those which were used against Japan: the hydrogen bomb.

The First Thermonuclear Weapons

The notion of using a fission weapon to ignite a process of nuclear fusion can be dated back to 1942 . At the first major theoretical conference on the development of an atomic bomb hosted by J. Robert Oppenheimer at the University of California, Berkeley, participant Edward Teller directed the majority of the discussion towards Enrico Fermi's idea of a "Super" bomb which would utilize the same reactions which powered the Sun itself. It was thought at the time that a fission weapon would be quite simple to develop and that perhaps work on a hydrogen bomb would be possible to complete before the end of the Second World War. However, in reality the problem of a "regular" atomic bomb was large enough to preoccupy the scientists for the next few years, much less the more speculative "Super." Only Teller continued working on the project - against the will of project leaders Oppenheimer and Hans Bethe.

Hungarian physicist Edward Teller toiled for years trying to discover a way to make a fusion bomb.

After the atomic bombings of Japan, many scientists at Los Alamos rebelled against the notion of creating a weapon thousands of times more powerful than the first atomic bombs. For the scientists the question was in part technical - the weapon design was still quite uncertain and unworkable - and in part moral: such a weapon, they argued, could only be used against large civilian populations, and could thus only be used as a weapon of genocide. Many scientists, such as Bethe, urged that the United States should not develop such weapons and set an example towards the Soviet Union. Promoters of the weapon, including Teller, Ernest Lawrence, and Luis Alvarez, argued that such a development was inevitable, and to deny such protection to the people of the United States - especially when the Soviet Union was likely to create such a weapon themselves - was itself an immoral and unwise act.

Oppenheimer, who was now head of the General Advisory Committee of the successor to the Manhattan Project, the Atomic Energy Commission, presided over a recommendation against the development of the weapon. The reasons were in part because the success of the technology seemed limited at the time (and not worth the investment of resources to confirm whether this was so), and because Oppenheimer believed that the atomic forces of the United States would be more effective if they consisted of many large fission weapons (of which multiple bombs could be dropped on the same targets) rather than the large and unwieldy predictions of massive super bombs, for which there were a relatively limited amounts of targets of the size to warrant such a development. Furthermore, were such weapons developed by both the U.S. and the USSR, they would be more effectively used against the U.S. than by it, as the U.S. had far more regions of dense industrial and civilian activity which would serve as ideal targets for the large weapons than the Soviet Union did.

In the end, President Truman made the final decision, looking for a proper response to the first Soviet atomic bomb test in 1949 . On 31 January 1950, Truman announced a crash program to develop the

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The "Ivy Mike" shot in 1952 inaugurated the age of fusion weapons.

hydrogen (fusion) bomb. At this point, however, the exact mechanism was still not known: the "classical" hydrogen bomb, whereby the *heat* of the fission bomb would be used to ignite the fusion material, seemed highly unworkable. However, an insight by Los Alamos mathematician Stanislaw Ulam showed that the fission bomb and the fusion fuel could be in separate parts of the bomb, and that *radiation* of the fission bomb could first work in a way to *compress* the fusion material before igniting it. Teller pushed the notion further, and used the results of the boosted-fission "George" test (a boosted-fission device using a small amount of fusion fuel to boost the yield of a fission bomb) to confirm the fusion of heavy hydrogen elements before preparing for their first true multi-stage, Teller-Ulam hydrogen bomb test. Many scientists initially against the weapon, such as Oppenheimer and Bethe, changed their previous opinions, seeing the development as being unstoppable. The first fusion bomb was tested by the United States in *Operation Ivy* on 1 November 1952, on Elugelab Island in the Enewetak (or Eniwetok) Atoll of the Marshall Islands, code-named "Mike". "Mike" used liquid deuterium as its fusion fuel and a large fission weapon as its trigger. The device was a prototype design and not a deliverable weapon: standing over 20 ft (6 m) high and weighing at least 140,000 lb (64 t) (its refrigeration equipment added an additional 24,000 lb as well), it could not have been dropped from even the largest planes. Its explosion yielded 10.4 megatons of energy - over 450 times the power of the bomb dropped onto Nagasaki - and obliterated Elugelab, leaving an underwater crater 6240 ft (1.9 km) wide and 164 ft (50 m) deep where the island had once been. Truman had initially tried to create a media blackout about the test - hoping it would not become an issue in the upcoming presidential election - but on January 7, 1953, Truman announced the development of the hydrogen bomb to the world as hints and speculations of it were already beginning to emerge in the press.

Not to be outdone, the Soviet Union exploded its first thermonuclear device, designed by the physicist Andrei Sakharov, on August 12, 1953, labeled "Joe-4" by the West. This created concern within the U.S. government and military, because, unlike "Mike," the Soviet device was a deliverable weapon, which the U.S. did not yet have. This first device though was arguably not a "true" hydrogen bomb, and could only reach explosive yields in the hundreds of kilotons (never reaching the megaton range of a "staged" weapon). Still, it was a powerful propaganda tool for the Soviet Union, and the technical differences were fairly oblique to the American public and politicians. Following the "Mike" blast by less than a year, "Joe-4" seemed to validate claims that the bombs were inevitable and vindicate those who had supported the development of the fusion program. Coming during the height of McCarthyism, the effect was most pronounced by the security hearings in early 1954 which revoked former Los Alamos director Robert Oppenheimer of his security clearance, on the grounds that he was unreliable, had not supported the American hydrogen bomb program, and had made long-standing, left-wing ties in the 1930s. Edward Teller participated in the hearing as the only major scientist to testify against Oppenheimer, a role which resulted in his virtual expulsion from the physics community.

On 28 February 1954, the U.S. detonated its first deliverable thermonuclear weapon (which used isotopes of lithium as its fusion fuel), known as the "Shrimp" device of the "Castle Bravo" test, at Bikini Atoll, Marshall Islands. The device yielded 15 megatons of energy, over twice its expected yield, and became the worst radiological disaster in U.S. history. The combination of the unexpectedly large blast and poor weather conditions caused a cloud of radioactive nuclear fallout to contaminate over 7,000 square miles, including Marshall Island natives and the crew of a Japanese fishing boat, as a snow-like mist. The contaminated islands were evacuated (and are still uninhabitable), but the natives received enough of a

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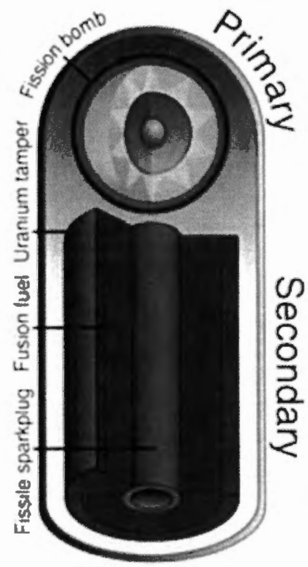
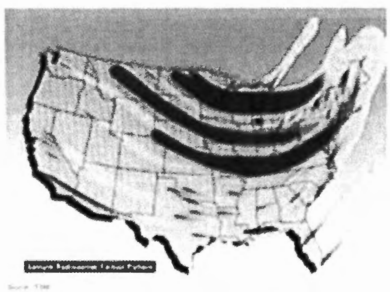
radioactive dose that they suffered far elevated levels of cancer and birth defects in the years to come. The crew of the Japanese fishing boat, *Fifth Lucky Dragon*, returned to port suffering from radiation sickness and skin burns. Their cargo, many tons of contaminated fish, managed to enter into the market before the cause of their illness was determined. When a crew member died from the sickness and the full results of the contamination were made public by the U.S., Japanese concerns were reignited about the hazards of radiation and resulted in a boycott on eating fish (a main staple of the island country) for some weeks.



The basics of the Teller-Ulam design for a hydrogen bomb: a fission bomb uses radiation to compress and heat a separate section of fusion fuel.



Fallout from a large nuclear exchange would potentially blanket a country - perhaps even the whole world - with radioactive fission products.

The hydrogen bomb age had a profound effect on the thoughts of nuclear war in the popular and military mind. With only fission bombs, nuclear war could be considered something which could easily be "limited." Dropped by planes and only able to destroy the most built up areas of major cities, it was possible to consider fission bombs simply a technological extension of previous wartime bombing (such as the extensive firebombing which took place against Japan and Germany during World War II), and claims that such weapons could lead to worldwide death or harm were easily brushed aside as grave exaggeration. Even the decades before the development of fission weapons there had been speculation about the possibility for human beings to end all life on the planet by either accident or purposeful maliciousness, but technology had never allowed for such a capacity. The far greater power of hydrogen bombs made this seem ever closer.

The "Castle Bravo" incident itself raised a number of questions about the survivability of a nuclear war. Government scientists in both the U.S. and the USSR had insisted that fusion weapons, unlike fission weapons, were "cleaner" as fusion reactions did not result in the dangerously radioactive by-products as did fission reactions. While technically true, this hid a more gruesome point: the last stage of a multi-staged hydrogen bomb often used the neutrons produced by the fusion reactions to induce fissioning in a jacket of natural uranium, and provided around half of the yield of the device itself. This fission stage made fusion weapons considerably more "dirty" than they were made out to be, a fact made evident by the towering cloud of deadly fallout which followed the "Bravo" test. When the Soviet Union tested its first megaton device in 1955 , the possibility of a limited nuclear war seemed even more remote in the public and political mind: even if a city or country was not the direct target of a nuclear attack, the clouds of fallout and harmful fission products would disperse along with normal weather patterns and embed themselves in the soil and water of non-targeted areas of the planet as well. Speculation began to look towards what would happen as the fallout and dust created by a full-scale nuclear exchange would affect the world as a whole, rather than just the cities and countries which had been directly involved. In this way, the fate of the world was now tied to the fate of the bomb-wielding superpowers.

Deterrence and Brinkmanship

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Throughout the 1950s and the early 1960s a number of trends were enacted between the U.S. and the USSR as they both endeavored in a tit-for-tat approach to disallow the other power from acquiring nuclear supremacy. This took form in a number of ways, both technologically and politically, and had massive political and cultural effects during the Cold War.

The emergence of nuclear-tipped rockets reflected a change in both nuclear technology and strategy.

The first atomic bombs dropped on Hiroshima and Nagasaki were large, custom-made devices, requiring highly trained personnel for their arming and deployment. They could be dropped only from the largest bomber planes - at the time the B-29 Superfortress - and each plane could only hold a single bomb in its hold. The first hydrogen bombs were similarly massive and complicated. This ratio of one plane to one bomb was still fairly impressive in comparison with conventional, non-nuclear weapons, but against other nuclear-armed countries it was considered to be a grave danger. In the immediate postwar years, the U.S. expended much effort on making the bombs "G.I.-proof" - capable of being used and deployed by members of the U.S. Army, rather than Nobel Prize–winning scientists, and in the 1950s a program of nuclear testing was undertaken in order to improve the nuclear arsenal.

Starting in 1951 , the Nevada Test Site (in the Nevada desert) became the primary location for all U.S. nuclear testing (in the USSR, Semipalatinsk Test Site in Kazakhstan served a similar role). Tests were divided into two primary categories: "weapons related" (verifying that a new weapon worked or looking at exactly how it worked) and "weapons effects" (looking at how weapons behaved under various conditions or how structures behaved when subjected to weapons). In the beginning, almost all nuclear tests were either "atmospheric" (conducted above ground, in the atmosphere) or "underwater" (such as some of the tests done in the Marshall Islands). Testing was used as a sign of both national and technological strength, but also raised questions about the safety of the tests, which released nuclear fallout into the atmosphere (most dramatically with the Castle Bravo test in 1954 , but in more limited amounts with almost all atmospheric nuclear testing).

Hundreds of nuclear tests were conducted at the Nevada Test Site in the USA.

Because testing was seen as a sign of technological development (the ability to design usable weapons without some form of testing was considered dubious), halts on testing were often called for as stand-ins for halts in the nuclear arms race itself, and many prominent scientists and statesmen lobbied for a ban on nuclear testing. In 1958 , the U.S., USSR, and the United Kingdom (a new nuclear power) declared a temporary testing moratorium for both political and health reasons, but by 1961 the Soviet Union had broken the moratorium and both the USSR and the U.S. began testing with great frequency. As a show of political strength, the Soviet Union tested the largest-ever nuclear weapon in October 1961, the massive Tsar Bomba, which was tested in a reduced state with a yield of around 50 megatons - in its full state it was estimated to have been around 100 Mt. The weapon was largely impractical for actual military use, but was hot enough to induce third-degree burns at a distance of 62 mi (100 km) away. In its full, "dirty" design, it would have increased the amount of worldwide fallout since 1945 by 25%.

In 1963, all nuclear and many non-nuclear states signed the Limited Test Ban Treaty, pledging to refrain

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from testing nuclear weapons in the atmosphere, underwater, or in outer space. The treaty permitted underground tests.

Most tests were considerably more modest, and worked for direct technical purposes as well as their potential political overtones. Weapons improvements took on two primary forms. One was an increase in efficiency and power, and within only a few years fission bombs were being developed which were many times more powerful than the ones created during World War II. The other was a program of miniaturization, reducing the size of the nuclear weapons themselves. Smaller bombs meant that bombers could carry more of them, and thus become even more of a threat against even the most rigorous air defenses, and they could also be used in conjunction with the development in rocketry during the 1950s and 1960s. U.S. rocket efforts had received a large boost in the postwar years, largely from the acquiring of engineers who had worked on the Nazi rocketry program during the war, such as Wernher von Braun, who had been involved in the design and manufacture of the V-2 rockets which were launched across the English Channel. An American program, Project Paperclip, had endeavored to move scientists of this sort into American hands (and kept out of Soviet hands) and put them to work on projects for the U.S.

Weapons Improvement

The first nuclear-tipped rockets, such as the MGR-1 Honest John, first deployed by the U.S. in 1953 , were surface-to-surface missiles with relatively short ranges (around 15 mi/25 km maximum) with yields around twice the size of the first fission weapons. The limited range of these weapons meant that they could only be used in certain types of potential military situations - the U.S. rocket weapons could not, for example, threaten the city of Moscow with the threat of an immediate strike, and could only be used as "tactical" weapons (that is, for small-scale military situations).

For "strategic" weapons - weapons which would serve to threaten an entire country - for the time being, only long-range bombers capable of penetrating deep into enemy territory would work. In the U.S. this resulted in the creation of the Strategic Air Command in 1946 , a system of bombers headed by General Curtis LeMay (who had previously presided over the firebombing of Japan during WWII), which kept a number of nuclear-armed planes in the sky at all times, ready to receive orders to attack Moscow whenever commanded.

Long-range bomber aircraft, such as the B-52 Stratofortress, allowed for a wide range of "strategic" nuclear forces to be deployed.

These technological possibilities enabled nuclear strategy to develop a logic considerably different than previous military thinking had allowed. Because the threat of nuclear warfare was so awful, it was first thought that it might make any war of the future impossible. Eisenhower's doctrine of "massive retaliation" in the early years of the Cold War was a message to the USSR, saying that if the Red Army attempted to invade the parts of Europe not given to the Eastern bloc during the Potsdam Conference (such as West Germany), nuclear weapons would be used against the Soviet troops and potentially the Soviet leaders.

With the development of more rapid-response technologies (such as rockets and long-range bombers), this policy began to shift. If the Soviet Union also had nuclear weapons and a policy of "massive retaliation" was carried out, it was reasoned, then any Soviet forces not killed in the initial attack, or launched while the attack was ongoing, would be able to serve their own form of nuclear "retaliation" against the U.S.

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Recognizing this to be an undesirable outcome, military officers and game theorists at the RAND think tank developed a nuclear warfare strategy that would eventually become known as Mutually Assured Destruction (MAD).

Submarine launched ballistic missiles made defending against nuclear war an impossibility.

MAD divided potential nuclear war into two stages: first strike and second strike. A first strike would be the first use of nuclear weapons by one nuclear-equipped nation against another nuclear-equipped nation. If the attacking nation did not prevent the attacked nation from a nuclear response, then a second strike could be deployed against the attacking nation. In this situation, whether the U.S. first attacked the USSR or the USSR first attacked the U.S., the end result would be that both nations would be damaged perhaps to the point of utter social collapse. According to game theory, because starting a nuclear war would be suicidal, no logical country would willfully enter into a nuclear war. However, if a country were capable of launching a first strike which would utterly destroy the ability of the attacked country to respond in kind, then the balance of power would be disturbed and nuclear war could then be safely undertaken.

MAD played on two seemingly opposed modes of thought: cold logic and emotional fear. The phrase by which MAD was often known, "nuclear deterrence", was translated as "dissuasion" by the French and "terrorization" by the Russians. This apparent paradox of nuclear war was summed up by British Prime Minister Winston Churchill as "the worse things get, the better they are" - the greater the threat of mutual destruction, the safer the world would be.

With early warning systems, it was thought that the strikes of nuclear war would come from dark rooms filled with computers, not the battlefield of the wars of old.

This philosophy made a number of technological and political demands on participating nations. For one thing, it said that it should always be assumed that an enemy nation may be trying to acquire "first strike capability," something which must always be avoided. In American politics this translated into demands to avoid "missile gaps" and "bomber gaps" where the Soviet Union could potentially "out shoot" American efforts (most of these supposed "gaps" proved to be political figments, but this hardly mattered at the time). It also encouraged the production of thousands of nuclear weapons by both the U.S. and the USSR, far more than would be needed to simply destroy the major civilian and military infrastructures of the opposing country.

The policy also encouraged the development of the first early warning systems. Conventional war, even at its fastest, was fought over time scales of days and weeks. With long-range bombers, the time from the start of an attack to its conclusion was reduced to mere hours. With rockets, it could be reduced to minutes. It was reasoned that conventional command and control systems could not be expected to adequately respond to a nuclear attack, and so great lengths were taken to develop the first computers which could look for enemy attacks and direct rapid responses. In the U.S., massive funding was poured into the development of Semi Automatic Ground Environment (SAGE), a system which would track and intercept enemy bomber aircraft using information from remote radar stations, and was the first computer system to feature real-time processing, multiplexing, and display devices - the first "general" computing machine, and a direct predecessor of modern computers.

Anti-Nuclear

Bombers and short-range rockets were not reliable: planes could be shot down, and earlier nuclear missiles could cover only a limited range - for example, the first Soviet rockets' range limited them to targets in Europe. However, by the 1960s, both the United States and the Soviet Union had developed intercontinental ballistic missiles, which could be launched from extremely remote areas far away from their target; and submarine-launched ballistic missiles, which had less range but could be launched from submarines very close to the target without any radar warning. This made any national protection from nuclear missiles increasingly impractical.

The military realities made for a precarious diplomatic situation. The international politics of brinkmanship led leaders to exclaim their willingness to participate in a nuclear war rather than concede any advantage to their opponents, feeding public fears that their generation may be the last. Civil defense programs undertaken by both superpowers, exemplified by the construction of fallout shelters and urging civilians about the "survivability" of nuclear war, did little to ease public concerns. A joke known by most Russians during the Cold War said that when one heard the air raid sirens, one should pick up a shovel and quietly proceed to the nearest cemetery, to dig your own grave. A similar joke in the U.S. recommended that one stay calm, put one's head between one's legs, and kiss your ass goodbye, a parody of the "duck and cover" routines practiced by schoolchildren across the country.

U-2 photographs revealed that the Soviet Union was stationing nuclear missiles on the island of Cuba in 1962 , beginning the Cuban Missile Crisis.

The climax of brinksmanship came in early 1962 , when an American U-2 spy plane photographed a series of launch sites for medium-range ballistic missiles being constructed on the island of Cuba, just off the coast of the southern United States, beginning what became known as the Cuban Missile Crisis. The U.S. administration of John F. Kennedy concluded that the Soviet Union, then led by Nikita Khrushchev, was planning to station Russian nuclear missiles on the island, which was under the control of Communist Fidel Castro. On October 22, Kennedy announced the discoveries in a televised address, and declared that a naval quarantine would be put around Cuba to turn back any Soviet nuclear shipments, and warned that the military was prepared "for any eventualities." The missiles would have a range of 2,400 miles (4,000 km), and allow the Soviet Union to easily destroy many major American cities on the Eastern Seaboard if a nuclear war were started.

The leaders of the two superpowers stood nose to nose, seemingly poised over the beginnings of a third world war. Khrushchev's ambitions for putting the weapons on the island were motivated in part by the fact that the U.S. had stationed similar weapons in Britain, Italy, and nearby Turkey, and had previously attempted to sponsor an invasion of Cuba the year before in the failed Bay of Pigs Invasion. On October 26, an offer was sent from Khrushchev to Kennedy offering to withdraw all missiles if Kennedy would commit to a policy of no future invasions of Cuba. Khrushchev worded the threat of assured destruction eloquently:

"You and I should not now pull on the ends of the rope in which you have tied a knot of war, because

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the harder you and I pull, the tighter the knot will become. And a time may come when this knot is tied so tight that the person who tied it is no longer capable of untying it, and then the knot will have to be cut. What that would mean I need not explain to you, because you yourself understand perfectly what dreaded forces our two countries possess."

A day later, however, the Russians put forward another offer, this time demanding that the U.S. remove its missiles from Turkey before any missiles would be withdrawn from Cuba. On the same day, a U-2 plane was shot down over Cuba and another was almost intercepted over Russia, and Soviet merchant ships were nearing the quarantine zone. Kennedy responded by accepting the first deal publicly, and sending his brother Robert to the Soviet embassy to accept the second deal in private. On October 28, the Soviet ships stopped at the quarantine line and, after some hesitation, turned back towards the Soviet Union. Khrushchev announced that he had ordered the removal of all missiles in Cuba, and U.S. Secretary of State Dean Rusk was moved to comment, "We went eyeball to eyeball, and the other fellow just blinked."

Nikita Khrushchev urged John F. Kennedy not to cut the "knot of war" created by nuclear deterrence.

The Crisis was later seen as the closest the U.S. and the USSR ever came to nuclear war and had been narrowly averted by last-minute compromise by both superpowers. Fears of communication difficulties led to the installment of the first hotline, a direct link between the superpowers which would allow them to more easily discuss future military activities and political maneuverings. It had been made clear that with their missiles, bombers, submarines, and computerized firing systems, the escalation of any situation to Armageddon could be done far easier than anybody desired.

After stepping so close to the brink, both the U.S. and the USSR worked to reduce their nuclear tensions in the years immediately following. The most immediate culmination of this work was the signing of the Partial Test Ban Treaty in 1963 , in which the U.S. and USSR agreed to no longer test nuclear weapons in the atmosphere, underwater, or in outer space. Testing underground continued, allowing for further weapons development, but the worldwide fallout risks were purposefully reduced, and the era of using massive nuclear tests as a form of saber-rattling had primarily ended.

In 1981, as U.S. President Ronald Reagan's administration pushed the arms race to new levels of higher tension with the USSR, one million people marched for nuclear disarmament and abolition in New York City. As the nuclear abolitionist movement grew, over 2,000 people were arrested in a two-day period in 1988 at the gate of the Nevada Test Site. Four of the significant groups organizing this renewal of anti-nuclear activism were Greenpeace, The American Peace Test, The Western Shoshone, and Nevada Desert Experience. Nevada Desert Experience (NDE) had kickstarted the renewal in 1982, and maintained annual resistance and prayer-actions for peace in Western Shoshone country (within Nevada) for 25 years.

Initial Proliferation

In the fifties and sixties, three more countries joined the "nuclear club."

The United Kingdom had been an integral part of the Manhattan Project following the Quebec Agreement

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in 1943 . The passing of the McMahon Act by the United States in 1946 unilaterally broke this partnership and prevented the passage of any further information to the United Kingdom. The British Government under Clement Attlee determined that it would be essential for there to be a British Bomb. Because of the involvement in the Manhattan Project Britain had extensive knowledge in some areas, but not in others. An improved version of 'Fat Man' was developed, and on 26 February 1952, Prime Minister Winston Churchill announced that the United Kingdom also had an atomic bomb and a successful test took place on the 3 October 1952. At first these were free-fall bombs and then there was a missile, Blue Steel, and a later-canceled medium-range ballistic missile, Blue Streak. Anglo-American cooperation on Nuclear weapons was restored by the 1958 US-UK Mutual Defence Agreement. As a result of this and the Polaris Sales Agreement, the United Kingdom has bought United States designs for submarine missiles and fitted its own warheads. It retains full independent control over the use of the missiles. It no longer possesses any free-fall bombs.

France had been heavily involved in nuclear research before World War II through the work of the Joliot-Curies. This was discontinued after the war because of the instability of the Fourth Republic and the lack of finance available.[1] However, in the 1950's a civil nuclear research program was started, a byproduct of which would be plutonium. In 1956 a secret Committee for the Military Applications of Atomic Energy was formed and a development program for delivery vehicles started. With the return of Charles de Gaulle to the presidency of France in 1958 the final decisions to build a bomb were taken, and a successful test took place in 1960 . Since then France has developed and maintained its own nuclear deterrent.

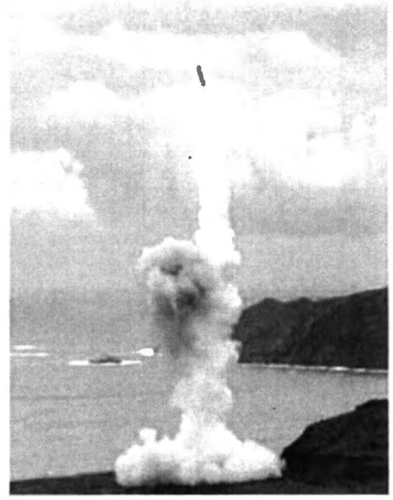
In 1951 China and the Soviet Union signed an agreement whereby China would supply uranium ore in exchange for technical assistance in producing nuclear weapons. In 1953 China had established a research program under the guise of civilian nuclear energy. Throughout the 1950's the Soviet Union provided large amounts of equipment, but as the relations between the two countries worsened, the amount of assistance was reduced, and in 1959 the donation of a bomb for copying purposes was refused. Despite this, rapid progress was made with the test of an atomic bomb on the 16th October 1964 at Lop Nur, a nuclear missile on 25th October 1966, and of a hydrogen bomb on the 14th June 1967. Nuclear warheads were produced from 1968 and thermonuclear warheads from 1974 . The Cultural Revolution slowed the pace of progress, but it is thought that tactical nuclear weapons have been developed. It is also thought that Chinese warheads have been successfully miniaturised from 2200kg to 700kg through the use of designs obtained by espionage from the United States. The current number of weapons is unknown owing to strict secrecy, but it is thought that up to 2000 warheads may have been produced, though far fewer may be available for use. China is the only one of the Nuclear Weapons States to have guaranteed the non-first use of nuclear weapons.

Cold War

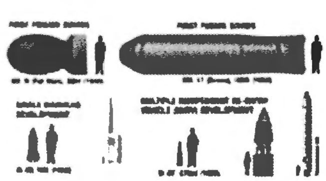
After World War II, the balance of power between the Eastern and Western blocs, resulting in the fear of global destruction, prevented the further military use of atomic bombs. This fear was even a central part of Cold War strategy, referred to as the doctrine of Mutually Assured Destruction ("MAD" for short). So important was this balance to international political stability that a treaty, the Anti-Ballistic Missile Treaty (or ABM treaty), was signed by the U.S. and the USSR in 1972 to curtail the development of defenses against nuclear weapons and the ballistic missiles which carry them. This doctrine resulted in a large increase in the number of nuclear weapons, as each side sought to ensure it possessed the firepower to destroy the opposition in all possible scenarios and against all perceived threats.

Early delivery systems for nuclear devices were primarily bombers like the United States B-29

Superfortress and Convair B-36, and later the B-52 Stratofortress. Ballistic missile systems, based on Wernher von Braun's World War II designs (specifically the V2 rocket), were developed by both United States and Soviet Union teams (in the case of the U.S., effort was directed by the German scientists and engineers). These systems, after testing, were used to launch satellites, such as Sputnik, and to propel the Space Race, but they were primarily developed to create the capability of Intercontinental Ballistic Missiles (ICBMs) with which nuclear powers could deliver that destructive force anywhere on the globe. These systems continued to be developed throughout the Cold War, although plans and treaties, beginning with the Strategic Arms Limitation Treaty (SALT I), restricted deployment of these systems until, after the fall of the Soviet Union, system development essentially halted, and many weapons were disabled and destroyed.



ICBMs, like the American Minuteman missile, allowed nations to deliver nuclear weapons thousands of miles away with relative ease.



Relative sizes of a number of nuclear weapons.

There have been a number of potential nuclear disasters. Following air accidents U.S. nuclear weapons have been lost near Atlantic City, New Jersey (1957); Savannah, Georgia (1958) (see Tybee Bomb); Goldsboro, North Carolina (1961); off the coast of Okinawa (1965); in the sea near Palomares, Spain (1966); and near Thule, Greenland (1968). Most of the lost weapons were recovered, the Spanish device after three months' effort by the DSV Alvin and DSV Aluminaut. The Soviet Union was less forthcoming about such incidents, but the environmental group Greenpeace believes that there are around forty non-U.S. nuclear devices that have been lost and not recovered, compared to eleven lost by America, mostly in submarine disasters. The U.S. has tried to recover Soviet devices, notably in the 1974 Operation Jennifer using the specialist salvage vessel *Hughes Glomar Explorer*.

On 27 January 1967, more than 60 nations signed the Outer Space Treaty, banning nuclear weapons in space.

The end of the Cold War failed to end the threat of nuclear weapon use, although global fears of nuclear war reduced substantially.

In a major move of de-escalation, Boris Yeltsin, on January 26, 1992, announced that Russia planned to stop targeting United States cities with nuclear weapons.

Further Nuclear Proliferation

India's first atomic-test explosion was in 1974 with Smiling Buddha, which it described as a "peaceful nuclear explosion". India tested fission and perhaps fusion devices in 1998 , and Pakistan successfully tested fission devices that same year, raising concerns that they would use nuclear weapons on each other. All of the former Soviet bloc countries with nuclear weapons (Belarus, Ukraine, and Kazakhstan) returned their warheads to Russia by 1996 , though recent data has suggested that a clerical error may have left some warheads in Ukraine.

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In January 2004 , Pakistani metallurgist and weapons scientist Abdul Qadeer Khan confessed to having been a part of an international proliferation network of materials, knowledge, and machines from Pakistan to Libya, Iran, and North Korea.

South Africa also had an active program to develop uranium-based nuclear weapons, but dismantled its nuclear weapon program in the 1990s. It is not believed that it actually tested such a weapon though it later claimed to have constructed several crude devices which it eventually dismantled. In the late 1970s American spy satellites detected a "brief, intense, double flash of light near the southern tip of Africa." [2] which was speculated to have been a South African nuclear weapons test, though a later scientific review of the data indicated that it may have been caused by natural events.

Israel is widely believed to possess an arsenal of potentially up to several hundred nuclear warheads, but this has never been officially confirmed or denied (though the existence of their Dimona nuclear facility was more or less confirmed by the leaks of the dissident Mordechai Vanunu in 1986).

North Korea announced in 2003 that it also had several nuclear explosives though it has not been confirmed and the validity of this has been a subject of scrutiny amongst weapons experts. The first detonation of a nuclear weapon by the Democratic People's Republic of Korea was the 2006 North Korean nuclear test, conducted on 9 October 2006.

In Iran, Ayatollah Ali Khamenei issued a fatwa forbidding the production, stockpiling and use of nuclear weapons on 9 August 2005. The full text of the fatwa was released in an official statement at the meeting of the International Atomic Energy Agency (IAEA) in Vienna.[3] Despite this, however, there is mounting concern in many nations about Iran's refusal to halt its nuclear power program, which many fear is a cover for weapons development.

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Nuclear Weapons

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Weapon Design

Teller-Ulam (Fusion)	Gun Type (Fission)	Implosion Type (Fission)	ICBM/SLBM	MIRV

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