＜論　　説＞

Is the Performance of Nuclear Weapons a Risk in Itself ?

Kazunobu Oyama

This study examines the relationship between technological performance and risk. Generally, high performance is associated with high risk. For example, in transportation systems, higher performance correlates with higher risks. With the increasing scale and speed of transportation, the risk also increases. Automobile accidents, which involve, vehicles with higher performance compared to bicycles, typically result in more serious consequence. Similarly, airplanes accidents, which have higher performance than automobiles, are more serious than automobile accidents.

This article examines the relationship between technological performance and risk in weapon development. Is the performance of a weapon itself a risk? Weapons often serve as deterrents, which are causal factors. In the case of weapons with tremendous destructive forces, such as nuclear weapons, controlling risk policies is important.

This article further explores the history of nuclear weapons development, their performance, associated risks, and control methods, which should not be avoided while discussing human civilization. First, we will examine the history of the development of nuclear weapons.

1. History of Atomic Bomb Development

In the 1800s, the atomic theory was studied in Greece and the existence of atoms was scientifically proven by 1897. The first Novel Prize in atomic theory was awarded in 1906. From 1892 to 1896, H. Nagaoka, a professor at Tokyo University, conducted studies in atomic physics at universities in Vienna, Berlin, and Munich.[1] An experiment demonstrated that uranium can produce tremendous energy, as predicted by A. Einstein, stimulating nuclear weapon development.

Manhattan Project in the United States

The Manhattan Project was a significant atomic bomb project during World War II. Germany has already pursued the development of nuclear weapons. Fission was first discovered in Germany, which has an ideal research infrastructure and government cooperation. A German scientists' group, The Uranium Club, comprised of theoretical physicists, experimentalists, and other academic colleagues who improved nuclear research and development (R&D).

J. Mahaffey points out that the Uranium Club made several mistakes, particularly, fatal errors, such as physicists participating in meetings and excluding Jewish scientists.[2] He indicates that nuclear R&D was limited without the contribution of pioneering Jewish atomic physicists including Einstein.

Moreover, not only Jewish scientists but also many others feared that Germany under A. Hitler might complete nuclear weapons development.[3] In 1932, the United States accepted the immigration of Einstein, a month before Hitler became Chancellor of Germany.

On September 1, 1939, World War II began, and on December 7, 1941, the Japanese Carrier Task Force attacked the American Naval Base in Pearl Harbor, Hawaii. Subsequently, President Roosevelt declared war on Japan. By December 1940, the British scientists' organization code MAUD concluded that nuclear weapons would sufficiently influence the war.

Moreover, the MAUD committee concluded that cooperation with the United States was inevitable in building nuclear weapons because of the lack of necessary resources for R&D projects in the United Kingdom. Based on this conclusion, Roosevelt organized the Uranium Committee, and the first meeting was held on October 21, 1940.

On December 1, 1942, an atomic bomb was assembled and all systems were green-lit. The US Army stored fissile U-235, which naturally exists at only 0.7%, and discarded the remaining 99.3% as non-fissile U-238 material. Miniaturizing the atomic bomb was the next problem, that is, to build a practical product. When the size of a graphite pile was miniaturized to a pineapple size, it became practical to drop a bomb from an airplane.[4]

Although nuclear theories and experiments were published in technical journals worldwide before World War II, all articles concerned with nuclear physics were instantly banned after the war because they became military secrets. Contemporaneous German and Japanese scientists were unware of the actual conditions in the Manhattan Project.

In July 1944, a uranium-based bomb was miniaturized to 10 feet, which was named "Little Boy" and could be vertically dropped from an airplane. In Little Boy, 64. Fifteen kilograms of U-235 enriched to 82.68% were used. By 1944, nuclear weapons development had proceeded smoothly without any obstacles.[5]

After the development of the uranium-based atomic bomb, the design of the plutonium-based bomb commenced. Within a short R&D period, a plutonium-based bomb, which was expected to perform better than a uranium-based bomb, was constructed. Due to misshapen appearance, the resulting sphere of explosive, which was 9 feet in diameter was named "Fat Man".

At 8:17 on August 6, 1945, Little Boy dropped from a B-29 bomber named "Enola Gay", which exploded at an altitude of 2,000 feet above Hiroshima, completely devastating the city, where 350,000 people lived, including American prisoners, German priests, and Asian laborers. However, Mahaffey mentions, "[. . .] but most of the bridges, roads, and rail lines were still usable".[6] The energy yield of Little Boy was estimated to be 16 kilotons of TNT. According to a Japanese government's investigation, fatalities numbered approximately 140,000 by the end of December 1945.[7]

At 11:02 on August 9, 1945, Fat Man dropped to Nagasaki, where approximately 210,000 people lived. The bomb exploded at a height of 1,600 feet at the north end of the city. The energy yield of the TNT was 21 kilotons of TNT. By the end of December 1945, fatalities were estimated to be 73,884, according to a report by the Atomic Bomb Materials Preservation Committee in July 1955.[8]

At 04:00 on the day the Fat Man was dropped at Nagasaki, Soviet Russia declared war against Japan by arbitrarily destroying a valid Japan-Soviet Neutrality Treaty, and their armies rushed into Manchuria. The Japanese government decided to terminate the war.

Atomic bomb development in Japan

At the end of the war, Japan undertook two projects concerned with the development of atomic bombs. One project was called "Nigo Research" at the Institute of Physical and Chemical Research (RIKEN), which started in May 1943 under the direction of the Army.[9] Research leader Y. Nishina and his colleagues were highly regarded experts in atomic physics. However, they could not find sufficient U-235 in Japan and escalated air attacks by the US Air Force destroyed their equipment.

In the first stage of research, scientists did not expect to develop atomic bombs that could be used because of a shortage of materials and unfavorable R&D circumstances. After serious efforts, they concluded that the project should be terminated in May 1945.

The other project, called "F go Research", was started at Kyoto University on almost the same date as "Nigo Research", it was organized by the Navy.[10] The project was led by B. Arakatsu and involved experts such as H. Yukawa, who later won a Nobel Prize in Physics in 1949. Although they obtained U-235 and developed the equipment, they faced many technological difficulties such as the centrifugation technology.

They concluded that the development of an atomic bomb was theoretically possible but practically impossible using existing Japanese technologies.

Competitions for atomic bomb development

After World War II, Soviet Russia considered the United States its rival although they were technical allies during the war. The Soviet government had a great interest in nuclear technology because of the formidable power of the atomic bombs displayed at the end of World War II. Soviet

Russia rapidly developed nuclear technology because of the competitive advantages of its backward countries.

To a certain extent, Soviet Russia imitated and used advanced nuclear technology and information from the United States. A. Gerschenkron analyzed backward countries' competitive advantage[11] and found that they could imitate advanced countries' successful technologies, manufacturing processes, and industrial institutions. Mahaffey mentioned that "The Soviet nuclear device was developed in a remarkably short time. By 1949, the RDS-1 bomb was ready for testing."[12] On August 29, 1949, Soviet Russia conducted its first nuclear bomb test, with a power of 22 kilotons of TNT, and stopped the nuclear monopoly of the United States.

After the 1950s, the focus of the competition between the United states and Soviet Russia shifted to developing a hydrogen fusion bomb (H-bomb). Owing to peer pressure, the competition scale and number of H-bomb tests increased. For example, in 1955, 1956, 1957, 1958, and 1961, the United States conducted 20, 30, 50, 105, and 140 above-ground nuclear tests, respectively. Rather than conducting numerous experiments, Soviets attempted to develop large-size H-bombs. On October 30, 1961, Soviet Russia conducted an H-bomb test, which yielded a power of 50 megatons, 3,125 times more powerful than Little Boy.[13]

During these periods, other countries participated in atomic bomb development competitions. For example, the United Kingdom conducted the first atomic bomb test on October 3, 1952, France conducted a similar test on February 13, 1960, and an H-bomb test on August 24, 1968. On October 16, 1964, China conducted atomic bombing tests.

Even after the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) was adopted in the United Nations General Assembly 1968, on May 18, 1974, India armed itself with nuclear weapons; on May 28, 1998, Pakistan did the same, and on October 9, 2006, so did North Korea.[14] According to Gerschenkron's theory, these backward countries relatively easily developed nuclear bombs due to the possibility of imitating and obtaining existing nuclear technology.[15]

2. Other Atomic Weapons Development

Mahaffey mentions, "A nuclear fuel would be at least a million times powerful than anything that could be achieved with chemicals."[16] The US Air Force and Navy were attracted to this formidable fuel. They have attempted to develop ships, submarines, aircraft, and rockets running on nuclear engines. The Army also envisioned battle-tanks with nuclear engines.

Nuclear engine aircraft carrier and submarine

Mahaffey indicated that the United States Navy had considered building a nuclear-powered aircraft carrier large enough to float bombers loaded with atomic weapons as early as 1947.[17] For the internal substructures of submarine reactors, zirconium is significant due to its ability to withstand high temperatures without melting or losing shape. However, it is more precious than platinum, and a single reactor requires a truckload.

By 1952 zirconium was being mined, milled, and produced in large quantities at low cost; consequently, nuclear-powered submarines became practical.[18] The first nuclear submarine named "Nautilus" was built in 1954. Moreover, the first nuclear-powered large aircraft carrier named "Enterprise" was put into practical use in 1961 after a long R&D period.

The main problems in R&D are miniaturizing nuclear reactors in ships and keeping them sufficiently secure to prohibit radioactive contamination. Nuclear-powered ships can cruise far longer voyages than diesel-powered ships without refueling them. The US Navy uses this advantage in its operations. Although Russia also has many nuclear submarines, except for the US Navy, only France has a nuclear-powered aircraft carrier named "Charles de Gaulle".

Nuclear rockets and airplanes

Mahaffey mentioned that the concept of nuclear-powered rockets and air-breathing jets had been under development since the middle of the Manhattan Project in World War II.[19] Even using the most efficient rocket fuel of the time, a combination of liquid hydrogen and liquid oxygen, it was almost impossible to reach the moon and much less likely to reach Mars with a manned spaceship. According to the R&D of the available nuclear rocket propulsion systems, a voyage to the moon and, a manned flight to Mars was impossible.

The main problem with R&D is the creation of a new material that can withstand the stress at thousands of degrees of temperature generated by nuclear rocket engine combustion. Moreover, the reactor had to be small and light, which is more difficult than in the case of submarines. By 1954, heavy-lift inter-continental ballistic missile (ICBM) systems were considered as counters for Soviet Russia.

The Joint Commission on Atomic Energy was organized in Los Alamos, and 100 million dollars were allocated to nuclear rocket–engine research and development, under strict military secrecy. In 1957, Soviet Russia successfully placed the first artificial satellite into orbit, that flew worldwide. The United States was immediately compelled to rush into the space program.

National Aeronautics and Space Administration (NASA) was established in 1958, and the Space Nuclear Propulsion Office was created in 1961. However, Mahaffey pointed out that "the nuclear rocket engine lacked something fundamental to a government-backed engineering program. It had no mission, no reason to be developed."[20] During the nuclear rocket engine R&D, a chemical rocket engine was developed. For example, the F-1 chemical rocket engine running on kerosene and liquid oxygen, and five boosters at the base of the rocket could lift the 6.7 million-pound Saturn-V spacecraft into the air. Nuclear rocket engine research and development is no longer a priority.

In 1946, the US Air Force organized Nuclear Energy for Propulsion of Aircraft and poured 10 million dollars into R&D efforts over two years. In 1951, the nuclear-bomber project was reorganized as the Aircraft Nuclear Propulsion Program（ANP）and continued the R&D efforts with high-tech companies such as General Electric and Pratt & Whitney. The US Air Force was attracted by the fact that nuclear-powered bombers carrying atomic bombs could fly around the world without refueling them.

However, nuclear-powered aircraft are far more difficult to construct than submarines owing to the need to use the lightest possible materials, and the use of lead is minimized in aircraft, whereas a submarine is a weighty vessel made of thick, pressure-resistant steel.[21]

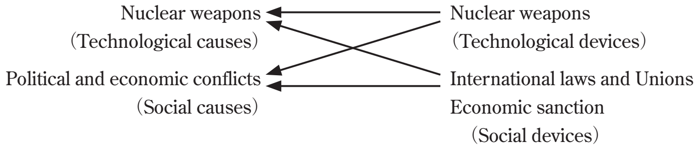
Protect the flight crew from irradiation using thinnest and lightest materials is another serious problem. Even the atomic airplane designated "NB-36", which flew 43 successful test missions in Texas, still raised questions concerning the radiation's effect on people and livestock on the ground as the nuclear-powered bomber flew over. For example, even a well-designed Pratt & Whitney airplane leaked so much radioactivity that nobody could approach the airplane once it landed. Radioactive contamination spread widely throughout the experimental area. Moreover, nuclear-powered aircraft accidents can cause disasters, especially air collisions, as serious as dropping bombs underground.[22]

In 1961, President Kennedy announced that the ANP program had been canceled because of the rapid progress of the ICBM program, which overran the ANP mission. ICBM can correctly deploy nuclear weapons at distant targets using chemically propelled rockets. The canceled ANP program cost $ 20 billion.

The US Air Force and Atomic Energy Commission（AEC）had another nuclear-powered aircraft project that was completely separate from and independent of the ANP program. Finally, in 1964, the development of nuclear jet engines ceased completely, and another $ 260 million went down the drain.[23]

Nuclear jet and rocket engines have become "dead-end technologies" [24] despite 18 years of R&D efforts by the AEC and NASA because of an unsolvable trade-off problem between light weight reactors and preventing radioactive materials from spreading irradiation.[25] Moreover, powerful chemical fuel rocket engines and progressing ICBM were other factors that pushed out the nuclear rocket- engines to dead-end technologies.

Figure 1. Causes of and solutions to nuclear weapon risk



3. Social Devices to Manage the Technological Risk of Nuclear Weapons

The discussion of the causes of and solutions to technological risks that I developed could be applied to the risk of nuclear weapons.[26] First, the most effective technological devices for restricting nuclear weapons risk are the nuclear weapons themselves. Second, social causes of risk include political and economic conflicts between countries. Third, social devices include international laws and unions.

I explained the “devil's solution”, which gets worse than the original problem.[27] Using nuclear weapons as a deterrent, that is, technological devices to mitigate risks (technological causes) that they pose as weapons, as well as political and economic conflicts (social causes), may be inclined to be the “devil's solution”, because of mutual nuclear competition and nuclear war possibility. Therefore, this section focuses on the effectiveness of social devices.

International laws of war and unions

Unfortunately, international laws and unions have limited effectiveness in controlling the risk of war. For example, the international law of war prohibits intentional attacks on innocent civilians, except in accidents involving damages.[28] Therefore, the projects fulfill the following four conditions; intentional planning, ordering, accepting, and executing attacks on civilians, which are against the international law of war.

In this context, including Hiroshima and Nagasaki, where there were several elementary schools and high-schools at the hypocenters, the US Air Force violated the law by bombing major cities in Japan.[29] Indeed, C. LeMay a U S Air Force general who directed the Tokyo air raid and other city bombings testified, “I suppose if I had lost the war, I would have been tried as a war criminal”[30] The effects of international laws are limited because of lack of sanctions against victorious countries.

Similarly, the United Nations and many other international unions and organizations have limited functions. For example, on May 2, 2022, the United Nations General Assembly Emergency Special Session adopted the “War of Aggression Against Ukraine by Russia” where 141 countries agreed, five objected, and 35 abstained. However, it could not restrict war.[31] Especially, permanent members' vetoes restricted the function of the United Nations.

The NPT contains 11 articles that were validated in 1976 and has a limited control function for the risk of nuclear weapons. However, these issues also have practical implications. Consequently, the treaty maintains the political advantage of nuclear weapon-armed states over non-armed states. Moreover, the 10th article it provides the withdrawal conditions. According to the article, member nations that assess serious risks to their national security can withdraw from the treaty. [32]

Actually, on March 12, 1993, North Korea declared its withdrawal from the NTP and intensively poured effort into nuclear weapons R&D. As I mentioned in Section 1 of this chapter, North Korea conducted the first atomic bomb experiment on October 9, 2006.[33] The decision with regard to "serious risks covering their national security", can be arbitrary.

Furthermore, non-member countries are not restrained by the NPT. International treaties, agreements, and unions are powerless social devices to solve the technological risk of nuclear weapons.

Economic sanctions

While international laws and unions do not have the power to impose sanctions, economic sanctions imposed through cooperation among multiple nations against a country violating international law are useful in restricting such violations to some extent. However, economic sanctions cause more serious political conflicts under some conditions. In such a case, the economic sanction becomes the "devil's solution".

On February 24, 2022, Russia began a full-scale invasion of Ukraine, and subsequently, western countries imposed economic sanctions against Russia, including an embargo on the import of Russian oil and gas and the export of various high-tech industrial parts. However, China supports the import of Russian oil and gas, whereas North Korea exports ammunition for artillery and missiles to Russia.

In this context, although economic sanctions have limited effectiveness over a short period, they become more impactful as time progresses.

4. Conclusion

Discussions on nuclear weapons cannot be avoided when investigating future nuclear technologies and civilization. Nuclear weapons technology may be a typical example of limited human rationality. The performance of nuclear weapons has become a risk in itself. How to manage and control such tremendous risk for future?

This article investigates the R&D and competition history of nuclear weapons, and analyzes the social devices to solve the formidable risk of nuclear weapons. We may conclude that international laws, unions, and other restrictions such as economic sanctions are extremely limited. Using only nuclear weapons as a deterrent is a useful solution that act as a technological device against the terrible technological risks they pose.

Humans will never destroy nuclear weapons until more powerful weapons are realized, notwithstanding every international law, union, cooperation, and peace movement.

Bibliography

1) Mahaffey, J. *Atomic Awakening –A New Look at the History and Future of Nuclear Power–*Pegasus Books, 2009

2) Mahaffey, J. Ibid. Part 2 Chap. 1

3) Hosaka, M.『日本原爆開発秘録』第一章　新潮文庫 2015. *Secret Document of Japanese Atomic Bomb R & D*, Chap. 1 Shinchobunko, 2015

4) Mahaffey, J. op. cit. Part 2, Chap. 3, p. 137

5) Mahaffey, J. Ibid. Part 2, Chap. 3, 4, pp. 154–157

6) Mahaffey, J. Ibid. Part 3, Chap. 5, pp. 302–303

7) The City of Hiroshima, *Home Page*, 2024

8) The City of Nagasaki, *City System 65 Years History*, 1959

9) Hosaka, M. op. cit. Chap. 3, 4

10) Hosaka, M. Ibid. Chap. 5

11) Gerschenkron, A. *Economic Backwardness in Historical Perspective*. Bleak House Books, Harvard, 1962

12) Mahaffey, J. op. cit. Part 3, Chap. 1

13) Mahaffey, J. Ibid. Part 3, Chap. 2, p. 232

14) Ministry of Foreign Affairs, *Disarmament, Non–Proliferation and Science Department's Report* 2019

15) Gerschenkron. A. op. cit.

16) Mahaffey, J. op. cit. Part 3, Chap. 2, p. 242

17) Mahaffey, J. Ibid. Part 3, Chap.2, p. 228

18) Mahaffey, J. Ibid. Part 3, Chap.1, p.217

19) Mahaffey, J. Ibid. Part 3, Chap.4, p.280

20) Mahaffey, J. Ibid. Part 3, Chap.4, p.297

21) Mahaffey, J. Ibid. Part 3, Chap.4, p.283

22) Mahaffey, J. Ibid. Part 3, Chap.4, p.290

23) Mahaffey, J. Ibid. Part 3, Chap.4, pp. 289–293

24) Oyama, K. "The future of nuclear technology" *The Studies in Economics and Trade The Annual Bulletin No. 46*, Kanagawa University 2020

25) Oyama, K. "The Trade-off Relationship between Technological Performances" *The Review of Economics and Commerce, Vol. 59 No.4*, Kanagawa University 2024

26) Oyama, K. "Nuclear Power Technology in Post-Industrial Civilization –A Comparative Study of France and Japan–" 1.4. https://hal.archives-ouvertes.fr/hal-03737847/document Fondation France-Japon de l'EHESS FFJ Discussion Paper #22-05, 2022「脱工業化社会における原子力発電—日仏比較研究—」『経済貿易研究』研究所年報　第 49 号 1-4.　神奈川大学経済学部 2023

27) Oyama, K. Ibid. 1.1.

28) Ogawa, K.『戦前国際法入門』［戦時編］　デザインエッグ　*Introduction to Prewar Law of War*, Design

Egg Ltd. Press 2018

29) Nishina Memorial Foundation　『原子爆弾』　光風社書店，*Atomic Bomb*, Kofusha Press 1973

30) McNamara, R. *The Fog of War*（Film）2003

31) Yanagihara, M.『帝国日本と不戦条約』　第 5 章　NHK ブックス，*The Empire of Japan and non–War Treaty*, Chap. 5, 2022

32) Suzuki, R. et al.『模範六法』　国際法　「核兵器の不拡散に関する条約」　三省堂，Complete Book of Six Law, International Law “Nuclear non-proliferation Treaty” Sanseido Press 2002

33) Ministry of Foreign Affairs, op. cit.