Report from the Committee of Experts on Damage Scenarios Resulting from a Nuclear Weapons Attack

November 9, 2007

Foreword

In compiling this Report, I had to start with an introspective inquiry. After all, the theme of the Report is a discussion of “casualty scenarios resulting from a nuclear weapons attack,” and the Report itself is a requirement of the Civil Protection Law. I am someone who, through the research I have conducted into radiation in Hiroshima, knows in great detail the damage wreaked by nuclear weapons. I am also someone who continues to hope that no such nuclear damage will ever be inflicted again. Furthermore, as an A-bomb victim, I have firsthand knowledge that there is no escape from the effects of nuclear weapons. As such a person, is it permissible for me to participate at all in drawing up “casualty scenarios resulting from a nuclear weapons attack”?

The Civil Protection Law assumes various scenarios of attacks on Japan and provides basic response guidelines for each. Included in these scenarios is a nuclear weapons attack. The guidelines for a nuclear weapons attack offers such obvious instructions as, “Flee immediately from the area near ground zero” and “When escaping, avoid going downwind.” However, they offer no indication of the extent to which such actions are possible. What is worse, no mention is made of the victims who would die instantaneously when the nuclear weapon explodes, either melting or turning into charred remains.

What intentions lay behind the creation of such guidelines? It being self-evident that protecting cities in the event of a nuclear attack is utterly impossible, are the authorities trying to ignore this fact and pave a path towards nuclear armament? The responsibility of protecting civilians rests principally with the central government. There is a limit to what local governments can do. If so, surely the only path open to Japan is not to rely on military might but to implement policies that will reduce the probability of an attack. These conclusions from my reflections made me hesitant to get involved with the Report.

When I voiced my concerns, officials of Hiroshima City responded as follows: “Hiroshima suffered immense damage from the human history’s first dropping of an atomic bomb. It is the mission of this city to ensure that the desire of the A-bomb victims is realized. That is, we must never to allow anybody else to undergo the same experience. The government’s basic guidelines are completely inadequate. They lack specific scenarios and predictions of casualties from a nuclear attack and lack policies or measures designed in accordance with those scenarios. This being the case, we requested the government to clarify projections of damage, but no response has been forthcoming. Also, 61 years have passed since the dropping of the atomic bomb. An increasing number of people are unable to imagine the horror of nuclear weapons. Therefore, Mayors for Peace called on its members to create damage scenarios for each city if nuclear weapons were used in cities around the world and the consequent global economic impact. They are asking their member cities to make their findings available to the rest of the world and guide public opinion towards nuclear disarmament. In this context and in the process of drafting the Civil Protection Plan, Hiroshima City believes that it is necessary to create casualty scenarios based on our A-bomb experience and all available scientific knowledge and information, thus revealing the immense scale of damage.”

It is 61 years since the atomic bomb was dropped on Hiroshima. Certainly, we have been fortunate not to have seen any offensive use of nuclear arms during these 61 years. However, many Japanese people no longer feel the menace of nuclear weapons. Or, perhaps they vaguely sense a threat but are unaware that they themselves are actually right at the heart of danger. Meanwhile, the proliferation of nuclear arms is a matter of global concern today, and even in Japan, comments are heard from within the government and the ruling party that seem to endorse Japan's possession of nuclear weapons. Some quarters in the United States are showing concern that Japan might arm itself with nuclear weapons. As we observe such developments in Japan and the world, it seems to me that identifying various issues relating to a nuclear weapons attack could be quite meaningful. Thus, I agreed to compile the Report.

Luckily, I was able to engage in serious discussions with members of our Committee of Experts over a wide range of areas. In our discussions, we concentrated on the casualty scenarios but we were also able to comment on ground surface explosions, which humanity has yet to experience. Still, however long we discuss the facts, we will never find a means of preventing damage in the event of a nuclear attack. Our conclusion is, the only answer is the total abolition of nuclear weapons. In addition to comments on casualties resulting from a nuclear weapons attack, we were able to describe the significance of nuclear weapons and the global situation today. We hope that these will provide a point of reference for future discussions of the nuclear weapons issue.

Finally, I wish to express my deep gratitude to the members of the Committee of Experts and to the research staff from Hiroshima University and other institutions for their cooperation in calculating and preparing damage data.

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Chapter 1: Introduction

1. History and Background

The Law concerning the Measures for Protection of the Civilian Population in Armed Attack Situations (Civil Protection Law) was enacted in June 2004. In accordance with this law, all national agencies and prefectural governments adopted their respective civil protection plans before the end of fiscal 2005.

In turn, most Japanese municipalities adopted civil protection plans of their own based on the plans of their prefectures, with reference to the Municipal Civil Protection Model Plan created by the Fire and Disaster Management Agency.

In support of this planning, the national government set forth its Basic Guidelines concerning the Protection of Civilian Population (cabinet approval in March 2005) and its Municipal Civilian Protection Model Plan (drafted by the Fire and Disaster Management Agency in January 2006). Listed among the armed attack scenarios is nuclear attack. However, no specific damage scenarios or response actions are proposed.

Fearing that the public could be drastically misled regarding the catastrophic damage a nuclear attack would inflict, Hiroshima City requested that the Japanese government assume responsibility for creating specific scenarios, revealing the findings, and indicating countermeasures. The government failed to respond. In view of this failure, Hiroshima City determined to carry out its own independent attempt at making predictions of damage, based on the city's nuclear experience, using all scientific knowledge and information available. As the first city in human history to be destroyed by an atomic bomb, Hiroshima believes it is duty-bound to publicize the tremendous damage that would result from a nuclear attack.

2. Purpose

Given this history and background, a Committee of Experts (Committee) was formed within the Hiroshima City Council for Civil Protection (Council) to deliberate the following: 1. the predicted damage in the event of a nuclear attack; and 2. the measures that Hiroshima City should adopt in view of that predicted damage. The Committee was to report on these matters to the Chairman of the Council, the Mayor of Hiroshima.

The Committee considered several possible scenarios, describing the damage that Hiroshima would suffer if it were attacked by nuclear weapons. Then, in light of its findings, the Committee evaluated the effectiveness of the measures and actions indicated by the government's Basic Guidelines and other guiding documents.

3. Outline of the Report

Before presenting predictions of damage and evaluating response measures, this Report first offers in Chapter 2 an overview of the current state of the nuclear shadow under which the world is living. Chapter 3 presents the general impact of a nuclear attack. Chapter 4 discusses predicted damage for the four scenarios created here: 1. a 16-kiloton (kt) nuclear weapon exploding 600 meters above the city center (the same as the atomic bombing of Hiroshima on August 6, 1945); 2. a 1-megaton (Mt) nuclear weapon exploding 2,400 meters above the city center; 3. a 16-kt nuclear weapon exploding on the surface in the city center; and 4. a 1-kt nuclear weapon exploding on the surface in the city center. Predicted damage and emergency measures will we presented for each scenario. Then, based on the content of Chapter 4, Chapter 5 will offer overall evaluations of the measures recommended in the Government's Basic Guideline and other official guidance. In Chapter 6, this Committee will present its conclusions on effectiveness and other aspects of the measures designated for implementation.

The number given inside the square brackets [ ] in the text refer to the number of the reference document listed on page 69ff. The specific methods applied in obtaining basic data and the damage estimates are given together in the Appendix at the end of the Report.

Key Units of Measure Used in the Report

[Yield] The energy released by an explosion is expressed as the equivalent conventional explosive TNT (trinitrotoluene). 1 kiloton (kt) is the equivalent of 1,000 tons of TNT and 1 megaton (Mt) is equivalent to 1 million tons of TNT.
[Radiation] The Report takes into consideration the differences in impact that radiation has on a human body depending on the type and amount of energy released by radiation. The unit of measure used for a radiation dose received by human tissue is the Sievert (Sv). 1Sv = 1,000mSv. The unit Gray (Gy) is the unit of radiation absorption, indicating the amount of radiation energy absorbed into matter or tissue. Sv includes weighting factors predicting the impact on a human body (this weighting factor is one for beta and gamma rays but 20 for alpha rays and between 5 to 20 for neutron radiation). The Report uses 10 as the weighting factor for neutrons.
[Pressure] Since the unit used in most reference documents is psi (pounds per square inch), the Report gives both psi and the SI unit of pascal (Pa). 1psi = 6.89476 $\times 10^3$Pa = 6.89476kPa.
[Heat] Likewise, thermal values are indicated in both the former unit, calories (cal), and the present unit, joules (J). (1cal = 4.18605J). 1MJ = 1 million J.

Chapter 2: Nuclear Weapons – Status and Threat

Before drawing up scenarios on the damage from a nuclear attack, we present a summary of the world situation with regard to nuclear weapons.

1. Actors in the Nuclear Armament Scene

At this point in time, when contemplating the possibility of an attack using nuclear weapons, six different actors must be identified. Not all the actors are sovereign states.

(1) Nuclear Weapon States recognized by the NPT
Five countries - the United States, Russia, the United Kingdom, France and China - are considered nuclear weapon states under the Nuclear Non-proliferation Treaty (NPT)[1], which went into effect in 1970.

(2) Nuclear Weapon States Not Party to the NPT
Three countries - India, Pakistan and Israel. India and Pakistan have tested their nuclear weapons and openly declare possession. Israel refuses to confirm or deny possession. The international community regards these three countries as de facto nuclear powers. None are parties to the NPT.

(3) Self-declared Nuclear Weapon State
The Democratic People's Republic of Korea (North Korea) has conducted nuclear testing. While claiming to be in possession of nuclear weapons, it is negotiating nuclear disarmament. Most members of the international community have declined to recognize North Korea as a de facto nuclear power. It was a party to the NPT, but withdrew.

(4) Non-nuclear-weapon States Reliant on Nuclear Weapons
Twenty six countries - 23 non-nuclear-weapon states that belong to the North Atlantic Treaty Organization (NATO)[2] including Germany and Italy, plus Japan, South Korea and Australia - are Parties to the NPT as Non-nuclear-weapon States but officially adopt policies that rely for their own security on nuclear weapons possessed by other countries.

(5) Non-state Actors That May Become Armed with Nuclear Weapons
So far, there is no clear evidence of any group other than sovereign states having nuclear arms. However, the international community fears that such possession may become reality and preventing this is a major concern.

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[1] Identifying the United States, Russia, the United Kingdom, France and China as nuclear powers, the Treaty obligates these nuclear-weapon states not to transfer nuclear weapons to non-nuclear-weapon states. Parties are also obligated to engage in good-faith nuclear disarmament negotiations. They are further obligated to accept the safeguard measures of the International Atomic Energy Agency (IAEA). The official name of the treaty is the Treaty on the Non-proliferation of Nuclear Weapons. It took effect in 1970. Japan ratified the Treaty in 1976. Its signatories currently number 190 countries (as of May 2007). Non-party states are India, Pakistan, and Israel. North Korea announced its withdrawal in January 2003.

[2] A security alliance formed in 1949 by 12 North American and European members in accordance with the North Atlantic Treaty. With 26 members at present, its headquarters are in Brussels, Belgium.

(6) Non-nuclear-weapon States Not Reliant on Nuclear Weapons
Other Parties to the NPT that are non-nuclear-weapon states pledge non-possession of nuclear weapons and have no security policy expressly reliant on the nuclear weapons of other states: the overwhelming majority of countries (82%) belong to this category (158 countries out of 193 countries [192 members of the United Nations and the Holy See]). Of these, 109 actively repudiate reliance on nuclear weapons through such actions as signing a Nuclear-Weapons-Free Zone Treaty.[3]

2. Long-term Nuclear Possession

The acknowledged nuclear weapon states still maintain that nuclear weapons are essential for their national security and declare their intention to possess nuclear weapons over the long term.

The US Government in its latest *Nuclear Posture Review* (January 2002) stated that "Nuclear weapons play a critical role in the defence capabilities of the United States" and called for a detailed study on the updating of nuclear weapons.[4] Furthermore, a recent report submitted to Congress (July 2007), "National Security and Nuclear Weapons: Maintaining Deterrence in the 21st Century" (A Statement by the Secretary of Energy, Secretary of Defense and Secretary of State) [2] states the conclusion that "…nuclear weapons will continue to be required for the foreseeable future." President Putin of Russia said in a recent speech that nuclear forces are a key factor in [Russia's] national security and [Russia] can be confident of [Russia's nuclear deterrent force] for decades.[5] Then President Chirac of France declared in a speech made 18 months ago that "nuclear deterrence remains the fundamental guarantee of our security."[6] Then British Prime Minister Blair, in a Defence White Paper of December 2006 that proposed the overhaul of the Trident nuclear weapons system, stated that maintaining nuclear weapons was the only means of deterring blackmail and acts of aggression.[7] China is the only one of the five that is not stressing the

[3] The Cook Islands and Niue, who are parties to the South Pacific Nuclear Free Zone Treaty, are not counted here because they are self-governing territories of New Zealand. Though Australia is a member of the South Pacific Nuclear Free Zone, it adopts a policy that is reliant on nuclear weapons and is therefore not counted. Mongolia has been given nuclear-free status by a UN General Assembly resolution and is therefore counted.

[4] "Nuclear weapons play a critical role in the defense capabilities of the United States, its allies and friends. (…) These nuclear capabilities possess unique properties that give the United States options to hold at risk classes of targets (that are) important to achieve strategic and political objectives."[1]

[5] "… nuclear forces, which are a key factor in our national security and in maintaining the balance of power and ensuring strategic stability in the world. … our nuclear deterrent force, about how we can be sure about it for some decades, and about how we are able to resolve any tasks, including penetrating missile defence systems, should such systems be created…"[3]

[6] "Such a defence policy rests on the certainty that, whatever happens, our vital interests remain safeguarded. This is the role assigned to nuclear deterrence, which directly stems from our prevention strategy and constitutes its ultimate expression. For in the face of the concerns of the present and the uncertainties of the future, nuclear deterrence remains the fundamental guarantee of our security."[4]

[7] "We can only deter such threats in future through the continued possession of nuclear weapons. Conventional capabilities cannot have the same deterrent effect. We therefore see an enduring role for the UK's nuclear forces as an essential part of our capability for deterring blackmail and acts of aggression against our vital interests by nuclear-armed opponents. We have thus decided to take the steps necessary to sustain a credible deterrent capability in the 2020s and beyond. "[5]

importance of nuclear weapons for national security but continues to hold the view that nuclear weapons should be held for the purpose of retaliatory action only.[8]

The Acknowledged Nuclear Weapon States in this way regard nuclear weapons as key weapons in ensuring their national security and continue to update or modernize their nuclear arms.

The United States has embarked upon the research and development of a simpler and tougher warhead of new design under the Reliable Replacement Warhead (RRW) program and is contemplating a Complex 2030 Plan to renew nuclear weapons production facilities with a view to manufacturing new warheads [7]. As it is designed to be completed in 2030, the Plan suggests that the US intends to keep their nuclear arms for decades. Meanwhile, Russia is engaged in the development of missiles that can readjust their course as they travel and can penetrate the US missile defence [3]. France is developing a new submarine-launched ballistic missile. Its first launch test was conducted in November 2006 [8]. China is said to be developing a new type of solid-fuel intercontinental ballistic missile (ICBM) and a new-generation missile-launching submarine and submarine-launched missiles [9]. The British Government proposed the renewal of the Trident missile system, its only nuclear weapon. This implies that it plans to possess nuclear weapons at least until 2050 [5].

In the context of these postures of long-term possession, there appear to be approximately 26,000 nuclear warheads on Earth at present. Details are given as data in Appendix B, Table B-1.

Such semi-permanent nuclear possession plans of the Acknowledged Nuclear Weapon States may be encouraging a similar desire for long-term possession among the Non-NPT Nuclear-weapon States and the Self-declared Nuclear Powers. In addition, it is probably a factor provoking Non-state Actors to seek to acquire nuclear weapons.

3. Greater Likelihood of Nuclear Weapons Use

The Acknowledged Nuclear Weapon States' policies assume the use of nuclear weapons. "For deterrence to work, the aggressor must be convinced that the deterrent forces can and will be used and will be effective when used [10]. " As this is elementary nuclear deterrence theory, it is a matter of course that nuclear powers are prepared and ready to use nuclear arms. Although nuclear weapons are frequently referred to as "political weapons," we must never forget that such expressions are based on this nuclear readiness.

[8] "China consistently upholds the policy of no first use of nuclear weapons, and adopts an extremely restrained attitude toward the development of nuclear weapons. China has never participated in any nuclear arms race and never deployed nuclear weapons abroad. China's limited nuclear counterattack ability is entirely for deterrence against possible nuclear attacks by other countries."[6]

In particular, the United States and Russia are believed to be still maintaining the advanced warning systems they created during the Cold War when a nuclear alert would straightaway lead to a launch situation. According to Bruce Blair, President of the World Security Institute (WSI) and former nuclear missile launch control officer, the United States are surmised to have 1,600 to 1,700 and Russia 1,000 to 1,200 nuclear warheads ready for press-and-fire [11].

What is more, after the 9.11 attack in 2001, additional scenarios for nuclear weapons use were envisioned, sparking fears that the "threshold" of nuclear weapons use has been lowered.

Firstly, the United States planned the development of weapons for actual battlefield use rather than deterrence. One example is a nuclear bunker buster[9] to be used to destroy underground fortifications, command rooms and factories, and the Agent Defeat Weapon (ADW) that will be used to destroy biological and chemical weapons [1]. Fortunately, the US Congress has refused in the past several years to authorize the development of these weapons. However, there are strong forces leaning towards the notion of battlefield use.

Secondly, of some relevance to this, the United States adopted a Global Strike Strategy that integrates the use of conventional and nuclear weapons. The Global Strike Strategy was conceived as part of the 2002 *Nuclear Posture Review* mentioned above. Long-distance, accurate strike capability on a global scale is positioned within an integrated concept of nuclear and non-nuclear weapons, with the delivery system to be created.[10] One manifestation was the proposal to convert some of the nuclear warheads of the submarine-launched Trident missiles into conventional weapons [13]. The command headquarters for Global Strike was set up within the US Strategic Command in January 2005. In August of that year, it became operational [14]. This approach blurs the distinction between nuclear and conventional weapons, leading to the lowering of the "threshold" of nuclear weapon use.

Thirdly, it was revealed that the United States is contemplating the use of nuclear weapons in a pre-emptive strike. That is, it came to light that the US Strategic Command Doctrine for Joint Nuclear Operations (draft) of March 2005 assumes the pre-emptive use of nuclear weapons [15]. Under vehement protest from Congress, the problematic wording was deleted from the final version of the Doctrine but the actual planning is thought not to have altered. Such a doctrine would lead many other countries to adopt a similar doctrine or reinforce a countermeasure, thereby creating a vicious cycle that would greatly increase the possibility of nuclear weapons use.

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[9] In order to destroy robust targets buried deep underground, this weapon first penetrates the ground surface and covering material (such as concrete), then detonates the nuclear warhead. The penetration capacity is limited and if used, a large amount of radioactive material will be dispersed over a large area above ground. Also known as a robust earth penetrator.

[10] In Arkin's words, the definition of Global Strike as referred to in the Presidential directive is "a capability to deliver rapid, extended range, precision kinetic (nuclear and conventional) and non-kinetic (elements of space and information operations) effects in support of theater and national objectives." [12]

Fourthly, in the "war on terror," guarantees of non-attack offered to non-nuclear states (negative security assurances) are becoming hollow promises. The above-mentioned Doctrine for Joint Nuclear Operations (draft) of the USA is one example. In the National Security Presidential Directives (NSPD)-17 of 2002, "National Strategy to Combat Weapons of Mass Destruction," the President makes it clear that the US will not refrain from nuclear retaliation against the use of weapons of mass destruction [16]. Then President Chirac of France made a speech in 2006 in a similar vein.[11]

Joseph Gerson in *Empire and the Bomb - How the US Uses Nuclear Weapons to Dominate the World* [17] lists cases of nuclear threat by nuclear powers after World War II and points out that so long as nuclear weapons exist, the threat of nuclear weapons use will persist. (For details, see Appendix B, Table B-2)

4. Nuclear Attack by Accident or Error

Apart from the increased possibility that nuclear weapons may be used in the course of combat, nuclear attacks may well occur as a result of accident or error. So long as nuclear weapons exist and are in an operational state, the occurrence of such error-induced tragedy cannot be ruled out.

Because the system of "press and fire" as referred to in 3 above is in operation, there is danger that a erroneous alert may be mistaken for a nuclear missile attack and the Big Red Button may be pushed. In the United States, after an alert is received, it takes 3 minutes for the duty crew to reach a preliminary conclusion. Then, an emergency teleconference is convened between the President and his top nuclear advisors. The time allowed for the top officer on duty at Strategic Command to explain the situation is roughly half a minute. The time allowed for the conference to come to a decision could range from zero to 12 minutes. In Russia, a much tighter timescale probably applies [18].

To cite an example of a post-Cold War incident, on January 25, 1995, a meteorological rocket launched off-shore of Norway was captured on Russia's early warning radar and the emergency alert escalated to the point of a retaliatory missile attack almost being fired at the USA. Norway had given prior notification, but for some reason this information was not relayed to the early warning radar base [19]. An example from the Cold War period is that of Russia's Lieutenant Colonel Stanislav Petrov, who was given the World Citizen Award for "saving the world from destruction" [11]. On September 26, 1983, when Petrov was on duty monitoring the USSR's early warning system, the alarm went off and the system showed him signals that could have meant the launch of 5 nuclear missiles from a US base. Although the system was confirmed to be operating properly, Petrov decided it was a false alarm and thus averted the crisis [20, 21]. Another example took place on June 3, 1980, when the computer display at the Strategic Air Command in Omaha, Nebraska showed "Colorado Springs Mission Command Center: Russia has launched a nuclear attack on the USA using multiple intercontinental ballistic missiles and submarine-

[11] The speech [4] includes the following: "the leaders of States who would use terrorist means against us, as well as those who would consider using, in one way or another, weapons of mass destruction, must understand that they would lay themselves open to a firm and adapted response on our part."

launched ballistic missiles" which led to air crews starting the engines of their nuclear-warhead carrying fighters and nuclear-warfare mission control planes. Mission control planes actually took off from Hawaii. Thus, a highly tense moment ensued but 3 minutes later, computer malfunction was discovered at the North American Aerospace Defence Command in Colorado Springs. The crisis was averted [22]. In a report later submitted to the US Senate, during the 18 months between January 1, 1979 and June 30, 1980, there were 147 alarms that indicated missile attacks on the US homeland. Of these, 4 are said to have led to the summoning of Threat Assessment Conferences [23].

Compounding this situation, the US Global Strike Strategy described above is heightening the risk of erroneous judgement about the occurrence of nuclear attack. As was mentioned earlier, if the program proceeds and long-distance precision strikes and initiated using conventional warheads on submarine-launched ballistic missiles, the danger is that the subjects of such attacks will perceive the conventional weapons attack as a nuclear attack and launch a nuclear counterattack. Currently, the USA, Russia and China have agreed to a prior notification system. However, if a Global Strike is implemented, there may be no time for prior notification, or the notification may not be relayed appropriately. Such accidents cannot be ruled out. What is more, if the enemy is a new nuclear power, especially North Korea, there are no such provisions of notification. The risk is much higher [24].

5. Nuclear Possession by Non-state Actors

Many stark warnings have been issued regarding the danger of Non-state Actors acquiring nuclear weapons. Even if countermeasures are instituted, there is virtually no information on which to base any action. Instead, at this point in time, preventive efforts are being focused on blocking the initial route of nuclear weapon acquisition by Non-state Actors. For example, the latest report by the US Council on Foreign Relations hypothesizes the following three routes and gives detailed consideration on how to block them [25].

(1) Theft of Nuclear Weapons
The US particularly fears that nuclear weapons belonging to Pakistan or Russia may get into the hands of a Non-state Actor. To prevent theft, the security system for weapons must be tightened and devices must be built into the weapons to prevent use even if they are stolen.

(2) Purchase of Nuclear Weapons
As a potential vendor, Pakistan under certain political circumstances could be a special source of concern. In addition to various diplomatic efforts, research is underway on methods of identifying the origin of nuclear weapons after use.

(3) Independent Manufacture of Nuclear Weapons
In this scenario, it would be almost impossible for a Non-state Actor to have the independent capability to produce either the plutonium or highly enriched uranium that is essential for a nuclear weapon. Therefore, it will be important to cut off all supply routes for these substances.

United Nations Security Council Resolution 1540 was adopted in April 2004 to prevent nuclear weapons or their materials from falling into the hands of Non-state Actors.[12] This Resolution obligated the international community to adopt effective laws which prohibit citizens and organizations of all member States from providing any Non-state Actor with materials or technology needed for weapons of mass destruction or to assist in their acquisition, or finance their acquisition.

We wish to point out that the international effort to sever these three routes, including the reinforcement of the practical effectiveness of UNSCR 1540, can be executed far more effectively and efficiently in a world where all states are legally banned from possessing nuclear weapons, compared to a world where some states are legally permitted to possess nuclear weapons.

6. Scenarios of Nuclear Attack on Japan

Given the current state of nuclear arms as outlined above, the threat that nuclear weapons pose to humanity is extremely severe. However, this threat is not directed at a specific country, such as Japan, but potentially involves the whole of humanity. Once nuclear weapons are used against a certain country, that country and its neighbors will suffer direct damage, and because of the power of nuclear weapons, unpredictable reactions are likely to occur. Enormous military, political, economic, social and cultural chaos and instability could ensue, including the possibility of additional nuclear attacks on other countries.

Because the international impact of nuclear weapons would be massive, any country planning to attack another will seek alternative modes of attack that are cheaper, more certain and more effective. Also, the decision to resort to nuclear weapons attack is not likely to emerge simply out of bilateral relations. For example, it is easy to talk of the “North Korean threat” and to assume a nuclear attack by North Korea on Japan, but the reality is that a far more complex web of international relations would prevail.

Therefore, singling out Japan as a potential target of nuclear attack is not necessarily appropriate as an issue for discussion. In this Report, we will bear this in mind and adopt a broader perspective in examining the scenarios of Japan becoming a direct target for nuclear weapons attack.

(1) Attack by a State

The possibility that Japan would become a target of attack by nuclear weapons is due in large part to Japan being an ally of the United States, the most powerful nuclear state in the world and one that adopts an offensive nuclear weapons policy. The US military bases and troops in Japan could become targets of attack, as could Japanese Self-Defence Force bases and troops and Japanese cities. We cannot rule out multiple and various targets coming under attack simultaneously. Some may argue that the possibility of retaliatory nuclear attack from the US serves as deterrent to Japan becoming subject to nuclear attack; however, uncertainty remains, that is, in order to avoid a nuclear attack on the US homeland, the US may not execute a retaliatory attack.

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[12] The Japanese translation of the UNSCR 1540 can be found on the Ministry of Foreign Affairs website - http://www.mofa.go.jp/mofaj/gaiko/un_cd/gun_un/pdfs/anpori_1540.pdf

In this scenario, the fact that Japan is a state reliant on nuclear weapons as described in 1 above will take on significance. The Acknowledged Nuclear Weapon States have pledged "negative security assurances" in a UNSC statement, that is, to refrain from using nuclear weapons against Non-nuclear Weapon States. Yet, the condition attached is that, with the exception of China, the allies of nuclear powers are not subject to this exclusion from attack [26]. Therefore, Japan, which is in alliance with the USA, is not subject to the "security assurance." It must be assumed that Non-NPT Nuclear Weapon States and Self-declared Nuclear Weapon States would adopt the same line.

Furthermore, as described in 4, Japan could become a target of attack through error or accident.

(2) Attack by a Non-state Actor

No one can categorically deny the possibility of a Non-state Actor attacking Japan. A theoretical scenario may be an attack on Japan because of our cooperation in the war against terror waged by the USA or because of mounting animosity against policies led by Japan. However, as explained in 5 above, it is more sensible for Japanese cities to direct effort toward measures that would prevent nuclear weapon attacks by a Non-state Actor rather than planning responses to such an attack.

Chapter 3: How Damage Results from the Use of Nuclear Weapons

1. What Is a Nuclear Weapon?

"Nuclear weapon" is the general term applied to an explosive device that derives its destructive force from nuclear energy liberated by nuclear fission or fusion.

Nuclear weapons using the nuclear fission of uranium-235 (U-235) or plutonium-239 (Pu-239) are called atomic bombs (A-bombs). The atomic bomb dropped on Hiroshima on August 6, 1945 used U-235; the atomic bomb dropped on Nagasaki on August 9, 1945 used Pu-239. Before these bombs were dropped, on July 16 of that year, the first atomic bomb in human history was tested in Alamogordo, New Mexico, USA. Like the Nagasaki bomb, it used Pu-239. The destructive power of the Hiroshima bomb was 16 kt; that of the Nagasaki bomb was 21 kt.

Depleted uranium shells[13] have been making headlines of late. The cores of these weapons are made of depleted uranium (mainly U-238) but they use only conventional explosives. Therefore, they are not classed as nuclear weapons.

Another kind of nuclear weapon is the hydrogen bomb (H-bomb). Its massive explosive force is derived from the nuclear fusion of hydrogen under the extremely high temperature and pressure generated by the fission of U-235 or Pu-239. Hydrogen is held in the form of lithium deuteride. The neutrons[14] emitted from a fission reaction react with the lithium to produce tritium. The tritium then fuses with deuterium to release more nuclear energy.

On March 1, 1954, the USA tested a hydrogen bomb on the Bikini Atoll in the central Pacific. This H-bomb was of a type that induces nuclear fission of uranium using neutrons that are produced by the nuclear fusion of hydrogen. It is referred to by the English acronym F-F-F bomb (fission-fusion-fission) or the 3F bomb. The yield of this H-bomb was about 15 Mt, some 940 times more powerful than the Hiroshima A-bomb. The total explosive power of all the bombs and shells used in the Second World War between 1939 and 1945, including the Hiroshima and Nagasaki A-bombs, was roughly 3 Mt. That means that this single Bikini hydrogen bomb was equivalent to five times the explosive force released during World War II. The hydrogen bomb that the former USSR exploded 4,000 meters above Novaya Zemlya Archipelago on October 31, 1961 was about 58 Mt in yield (about 3,600 times the Hiroshima bomb and 19 times the World War II equivalent). This is the largest nuclear test conducted to date.

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[13] Depleted uranium (DU) is radioactive waste primarily composed of U-238, a by-product of enriching natural uranium. Exploiting the extremely hard and heavy properties of uranium, the depleted uranium shell was created to penetrate armored plates of tanks. The fine particles of DU that scatter on impact enter into the human body and adversely affect health as well as create environmental pollution.

[14] A particle that comprises the atomic nucleus; produced from the nuclear fission of U-235 or Pu-239. Neutron radiation, which is a stream of neutrons, flies through the air over long distances and readily penetrates deep inside the human body. Because of this, it is a huge menace as a source of radiation exposure originating outside the body.

The neutron bomb is a special type of hydrogen bomb that minimizes blast and thermal radiation while maximizing neutron and gamma radiation[15]. As such, it is also known as a Radiation Enhanced Weapon (REW). The yield of the neutron bomb (blast and thermal radiation) is said to be only about one tenth that of the Hiroshima and the Nagasaki bombs. Its chief purpose is to paralyze and disable an enemy force using a vast amount of radiation.

In addition, it is still possible that the USA might undertake the development of new types of special nuclear weapons for various purposes. One example is the nuclear bunker buster, designed to destroy a military command center housed deep underground.

Another feature of nuclear weapons is that they are all integrated with a “means of delivery,” such as missiles or bombers that convey them to the enemy targets. Missiles are broadly categorized as ballistic missiles or cruise missiles. They can be launched from the ground or from aircraft and submarines. The Hiroshima and the Nagasaki A-bombs were dropped on those cities from an altitude of approximately 9,600 meters by B29 strategic bombers that flew in from Tinian Island.

The combat use of nuclear weapons requires a Command, Control, Communication and Intelligence System (C^3I System) to assess the combat situation, set the target and accurately deliver the nuclear warhead.

Nuclear weapons were originally developed by an atomic bomb development program called the Manhattan Project launched in 1942 by the USA. The weapons were actually used in combat in 1945. Sovereign states possessing nuclear weapons are increasing in number. The USA and the former Soviet Union (now Russia) developed them in the 1940s. They were followed by Britain in the 1950s, by France and China in the 1960s, India in the 1970s, Pakistan in the 1990s, and North Korea in the 2000s. Israel began developing them in the 1960s and is reported to have first deployed them for possible combat use during the Third Arab-Israeli War in 1967.

The context of these developments is the policy of “nuclear deterrence,” which seeks to prevent war through the threat of nuclear weapons. However, the context also included the dangerous policy of using nuclear weapons as an instrument of diplomacy. In reality, the presence of nuclear weapons has not prevented war, but it has posed a continuous threat to human civilization through the damage caused by their production and testing, the danger of nuclear accidents, vertical and horizontal proliferation, and the increasing danger of nuclear weapons use by sovereign states and terrorist groups.

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[15] If the atomic nucleus has excess energy, it emits this energy in the form of electromagnetic waves called gamma rays. Gamma rays move through the air over long distances and readily penetrate deep inside the human body. Gamma radiation is a source of exposure originating outside the body and, as such, is a serious menace.

2. Damage from Radiation

(1) Nuclear Explosion and Radiation Exposure

In an atomic explosion, roughly 15% of the total energy is emitted as radiation, of which 5% is believed to be initial radiation and 10% residual radiation.

When a nuclear weapon is detonated (defined as the start of nuclear fission), the ionizing radiation occurs before any visible phenomena[16]. Neutrons and gamma rays are released by the nuclear fission reaction of U-235 or Pu-239. Most of the initial radiation is emitted during this time, which means that people nearby are exposed to a lethal dose of radiation and doomed to die even before the light flash, heat, and blast. In a hydrogen bomb, the radiation from a nuclear fission reaction is used to start a nuclear fusion reaction of deuterium and tritium, which are forms of hydrogen atoms. This explosion also emits a vast amount of ionizing radiation in the form of neutrons and gamma rays. Included in the radiation are gamma rays derived from neutrons that hit and split the nuclei of atoms in the iron of the casing around the bomb. Gamma rays are emitted from various by-products of the fission of U-235 or Pu-239. The radiation emitted through all these processes within the first minute after detonation is referred to as “initial radiation.”

This radiation decreases in intensity as it gets absorbed by the atmosphere. The air that absorbs the radiation energy is heated to ultra-high temperatures and emits electromagnetic waves at wavelengths perceived as heat. During the ultra-high temperatures of the initial stage, X-rays are emitted. As the temperature descends, electromagnetic waves of longer wavelengths are emitted, going from ultraviolet rays to visible rays, then to infrared rays. The air within the range of temperatures that emit visible rays is observed as a “fireball”. The explosion also produces a powerful electromagnetic pulse caused by electromagnetic induction. This pulse is the result of gamma rays knocking electrons out of oxygen and nitrogen atoms in the air. This phenomenon will be discussed further in 5-(1).

The neutrons and gamma rays emitted from the epicenter lose intensity proportionate to distance and reach the surface of the earth, irradiating people, buildings and the ground. The dose of neutron and gamma radiation received by an individual human being is evaluated using a system called DS02 (Dosimetry System 2002)[17].

The neutron radiation showered on buildings and the ground activates the atomic nuclei of ^{23}Na (sodium-23), ^{31}P (phosphorus-31), ^{59}Co (cobalt-59), and ^{151}Eu (europium-151) in the building materials and soil, turning them into the radioactive nuclides ^{24}Na (sodium-24, half-life = 15 hours), ^{32}P (phosphorus-32, half-life = 14 days), ^{60}Co (cobalt-60, half-life = 5.277 years), ^{152}Eu (europium-152, half-life = 13

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[16] Ionizing radiation is radiation that, when passing through matter, has the capacity to displace electrons from their orbits, thus ionizing the atoms that constitute the matter affected. Alpha rays, beta rays, gamma rays and neutron radiation are all forms of ionizing radiation. The electrons displaced by ionization and the atoms that have thus lost their electrons can directly or indirectly damage DNA, causing a variety of disorders in the human body.

[17] Approved on March 15, 2003, this is a system used by the Radiation Effects Research Foundation to measure the radiation dose of the A-bomb survivors of Hiroshima and Nagasaki. The system used previously (DS86) was reviewed and amended. At this time, the yield of the Hiroshima A-bomb was revised from 15 kt to 16 kt and the explosion height from 580 meters to 600 meters.

years), producing what is referred to as residual radiation. These radioactive nuclides are produced in proportion to the amount of neutron radiation. The radioactive materials produced in building materials and soil in turn emit beta rays[18] and gamma rays. Therefore, even people not exposed to initial radiation can suffer radiation exposure if they enter the vicinity of ground zero while the residual radiation remains.

A wide variety of fission by-products are first lifted into the sky in the mushroom cloud, then some descend on the surrounding area as radioactive fallout. Fallout is also considered residual radiation. At times, it precipitates out as so-called "black rain," a sticky, heavy-oil-like rain containing soot and dust from the fires resulting from the nuclear attack. No accurate prediction of the range or intensity of this black rain is possible. Nuclear fallout may also contain some of the U-235 and Pu-239 that did not undergo nuclear fission. U-235 and Pu-239 are nuclides that emit alpha rays. Alpha rays[19] can only advance 3 to 3.5 centimeters through air, so there is no danger of radiation exposure outside the body. However, when they are inhaled or ingested, they become subject to consideration in this context.

To summarize, the radiation exposure caused by a nuclear weapons attack results from the following: 1) Initial radiation (neutrons and gamma rays emitted within the first minute or so after detonation); 2) Residual radiation emitted from radioactive nuclides produced inside soil or building materials due to exposure to neutron radiation; 3) Residual radiation emitted from fission by-products in fallout; and 4) Residual radiation from unfissioned nuclear material (U-235, Pu-239). Thus, consideration of radiation exposure must include sources outside the body (external exposure) in the case of 1), as well as external exposure and exposure from inside the body due to ingestion (internal exposure) in the case of 2) and 3), and internal exposure in the case of 4).

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[18] Some types of radioactive nuclei emit electrons when they are destroyed. The electrons emitted are called beta particles and a stream of beta particles is called a beta ray. The beta ray can only travel several millimeters into a human body but can travel several meters through air. If nuclides that emit beta rays enter the human body, they pose a grave threat. Even outside the body, if the source is close, they can damage exposed skin.

[19] When the heavy radioactive nucleus of a substance like uranium splits, a helium nucleus is emitted. This nucleus is an alpha particle and a stream is an alpha ray. The alpha ray can travel only 2 to 3 centimeters through air and only about a thousandth of that into a human body. It can be blocked even by a piece of paper. Thus, an alpha-ray emitting nuclide outside the body presents little danger; however, if such a source is ingested, the danger is grave.

There are four principal methods of estimating the radiation dose to which a human body is exposed.

Table 3-1 Methods of estimating radiation dose

Method	Details
Referring to acute radiation injury symptoms	In the acute phase, the correlation between the dose and the timing of the appearance of symptoms such as nausea and vomiting is useful as a rough measure of radiation dose (See Table 3-3.)
Referring to the change over time in the number of lymphocytes	Lymphocytes are highly sensitive to radiation and decrease in number in proportion to the dose of exposure. That is, exposure to 0.5 to 1.0 Sv reduces lymphocytes by about 25%, 1.0 to 3.0 Sv reduces them by 50% to 90%, and 3 to 10 Sv nearly eliminates them. (See Table 3-3.)
Estimating internal radiation using principles of physics	There are two main methods. One is external dosimetry. When an ingested radioactive material emits gamma rays (e.g. ^{60}Co, ^{137}Cs, ^{131}I, and ^{54}Mn), a special instrument is used from outside the body (whole body counter for the entire body or thyroid monitor for the thyroid gland). The other method is called the bioassay. To detect nuclides emitting alpha or beta rays (e.g. ^{3}H, ^{90}Sr, ^{235}U and ^{239}Pu), blood, urine or stool specimens are analyzed chemically.
Counting chromosomal abnormalities in peripheral blood lymphocytes	Lymphocytes include groups of cells that divide once every five to ten years. When dormant lymphocytes are awakened using special stimulants and their chromosomes examined, the injury received at the time will be revealed, and by counting the number of injuries (chromosomal abnormalities), the radiation dose at the time can be estimated. This is the most sensitive method of all the four methods given here.

Internal radiation exposure when by-products of nuclear fission or unfissioned nuclear materials are inhaled or ingested show complex variations in effect according to the type of radioactive nuclide (for example, uranium or cobalt) and its behavior inside the human body (e.g. inhalation rate, transfer to organ, distribution to multiple organs, retention time in organ, biological half-life in metabolized form).

For example, ^{54}Mn (manganese-54) enters into the body through inhalation and swallowing but only 10% of intake is absorbed by the digestive tract. The manganese is retained in the liver, the spleen and the lung. The physical half-life is 314 days but the biological half-life in metabolized form is 25 days. ^{54}Mn (manganese-54) is a nuclide that has been studied in detail, but the behavior of most radioactive nuclides inside the body is unknown. Thus, internal radiation dosimetry for the numerous radioactive substances produced by a nuclear explosion is extremely difficult.

Research on the internal radiation exposure of the Kamo battalion, which worked near the West Parade Ground for one week beginning early in the morning the day after the atomic bombing of Hiroshima 62 year ago, has produced an estimated exposure of 0.1 Gy.

(2) Acute Radiation Syndrome

When a human body is subject to radiation, ionization occurs within cells, injuring the genes located within the nucleus and leading to a variety of bodily disorders. The degree and manifestations of these injuries differ according to diverse factors.

Table 3-2 Factors affecting the effects of radiation on the human body

Factor	Details
Radiation dose	The greater the dose, the greater the disorder.
Extent of exposure	If more than one part of the body is exposed, the effects are greater.
Part of body	Other exposure factors being equal, the effects are greater on the torso, which contains vital organs, than on the limbs.
Dose rate	The greater the dose received per unit of time, the greater the effects.
Type of exposure	In the case of internal exposure, the tissues on which radioactive substances settle, and in the case of external exposure of the entire body, various parts of the body are affected.
Type of radiation	The effect on the human body differs by type of radiation.
Age of subject	Given the same dose, young people suffer greater effects because cells are dividing more rapidly.
Time lapse after exposure	Acute radiation syndrome in the early stages after exposure; cancer and blood vessel disorders emerge after a long period.

The damage wrought by radiation can be divided into acute radiation syndrome (ARS), which appears within months of exposure, and disorders that appear after a long period of latency (aftereffects).

ARS is due to cell death caused by damaged genes. The greater the dose, the worse are the symptoms. Cells tend to die more easily in tissues and organs where cells divide frequently, such as blood-forming tissues, digestive tracts, reproductive organs and the skin. For example, because stem cells are the prime movers of cell division, if a stem cell dies in blood-forming tissue, various blood cells decrease in number. If the symptoms are severe, the subject dies through infection or bleeding. Therefore, such patients are given treatment to prevent infection and bone marrow transplants.

Tables 3-3 and 3-4 show the correlation between radiation dose and ARS when exposed to a large dose of radiation in a relatively short time. If specialist treatment can be properly administered soon after exposure, even with a semi-lethal dose (4 Sv) shown in Table 3-4, more than half the victims have hope of survival. However, after a real attack, it will be impossible to administer proper treatment to the vast number of victims that will need it.

Table 3-3 Radiation dose and ARS (Source: See Reference [27].)

Dose (Sv)	0-0.5	0.5-1.0	1.0-2.0	2.0-6.0	6.0-10	10-20
Symptoms affecting whole body						
Physical symptoms that appear later	—	—	Languor	Hair loss	Bleeding	Diarrhea, fever
Time lapse till nausea and vomiting occur	—	—	3 hours	2 hours	1 hour	30 minutes
Blood abnormality						
Lymphocyte	—	Slight decrease	50% decrease	Considerable decrease	500/μℓ or less	0

* 1ℓ = 1,000,000 μℓ (microliters)

Table 3-4 Radiation per instance and effects on the human body (Source: Homepage of Department of International Health and Radiation Research, Atomic Bomb Disease Institute, Graduate School of Biomedical Sciences, Nagasaki University)

250 mSv or less	No physical symptom
500 mSv	Leukocytes temporarily decrease
1,000 mSv	Nausea, vomiting
1,500 mSv	50% of victims suffer radiation hangover (similar to alcohol hangover)
2,000 mSv	5% of victims die
4,000 mSv	50% of victims die in 30 days (semi-lethal dose)
7,000 mSv	100% of victims die

(3) Aftereffects

The mutation of cells due to gene damage cause aftereffects – the various health problems suffered by radiation victims after periods of latency. These can appear twenty or fifty years later, depending on the affected organ. For example, radiation cataracts can appear years after exposure, and exposure in infancy can permanently retard growth and development. Exposure in the womb can lead to microcephaly, accompanied by mental disability. Hyperparathyroidism, which manifests as abnormal calcium metabolism, or hypothyroidism can appear after several decades.

Exposure to high doses can lead to brain and cardiovascular disorders (cerebral infarction, myocardial infarction) in middle age. The most lethal of the late radiation disorders is cancer. Cancer appears after a latency period that differs by the affected organ. Leukemia emerges at a high frequency after five years, thyroid cancer after ten years, breast and lung cancer after twenty years, stomach and colon cancer after thirty years, and skin cancer and meningioma (a type of brain tumor) after forty years. These are not the only cancers caused by radiation; many others have been reported [28]. After the age of sixty, a second or third cancer may occur. The special characteristics of cancer caused by radiation are: 1) the greater the radiation dose, the more likely the victim is to develop cancer; 2) the younger the victim at the time of exposure, the more likely s/he is to develop cancer; and 3) the victim develops cancer when s/he reaches the likely age for that cancer. In short, radiation exposure leads to the extremely unfortunate encountering of various unexpected diseases deriving from genetic abnormality when exposed victims reach the latter stages of their lives.

3. Damage from Blast

About 50% of the energy emanating from a nuclear explosion takes the form of shockwaves and blast.

The high-temperature fireball formed by a nuclear reaction expands at supersonic speed, creating shockwaves at its extremity. The strength of the shockwave varies according to the yield of the nuclear warhead and the height of the explosion, but immediately after the explosion it grows with the fireball. The shockwave eventually separates from the surface of the fireball and propagates concentrically. It is a pressure wave (compression wave) that flattens anything at its point of arrival. (It works like a rapid rise in pressure; overpressure)

If a nuclear explosion occurs in mid-air, a reflected shockwave is created when the initial shockwave reaches the ground. The waves interact and double the destructive force (the Mach Effect). For the Hiroshima bombing, it was calculated that an explosion 600 meters above ground would maximize the destructive force of the shockwaves [29]. A nuclear attack intended to destroy underground military installations or other such facilities would explode the weapon on the ground surface (subsurface, if a nuclear bunker buster is used) to propagate the powerful shockwaves into the earth and direct the destruction underground.

After the shockwave, the flow of air pushed out by the rapid expansion of the fireball turns into a blast wind, which rages through the air, destroying buildings and killing people. The blast blows away anything in its path, with the pressure arising from the movement of air (dynamic pressure).

At ground zero, the rapid rise of the fireball creates a strong updraft, resulting in a dramatic lowering of atmospheric pressure, which eventually causes a vast volume of air to blow back toward the epicenter. Film recordings of nuclear tests show that buildings appear to be pushed outward immediately after the explosion, then get drawn back towards the direction of the epicenter. Such behavior is due to this "negative phase of the blast wave."

The effects of blast on the human body include direct effects, such as lung damage, eardrum rupture, and dislocation of internal organs or eyeballs [30] Indirect effects include collision with the ground or structures when blown by the blast, getting caught in the collapse of buildings, or being hit by flying debris.

Table 3-5 Pilot values relating to the direct effects on the human body of rapidly rising, long-lasting pressure pulse (Source: See Reference [31].)

Effect	Effective Maximum Overpressure (range) Unit: psi
Lung damage:	
Threshold	12 (8-15)
Severity	25 (20-30)
Lethal dose:	
Threshold	40 (30-50)
50%	62 (50-75)
100%	92 (75-115)
Eardrum rupture	
Threshold	5
50%	15-20 (aged 20 or over), 30-35 (under 20)

* The data for lung damage and lethality are extrapolations of animal data on humans; the values inside parentheses indicate dispersion of results. The data for eardrum rupture are based on relatively limited data on humans and animals.

As shown in Table 3-5 in Reference [31], the human body can withstand a considerable direct impact. Thus, indirect effects are the chief causes of casualties. For instance, the threshold value[20] for eardrum rupture is 5 psi (34.5 kPa) of overpressure. This pressure is believed to be sufficient to collapse a house. Indirect effects occur at much lower levels of overpressure. However, the number of casualties depends not only on the strength of the blast but also on the location and the surrounding environment.

4. Damage from Thermal Radiation

Roughly 35% of the energy liberated by a nuclear explosion takes the form of thermal radiation.

Inside the super-hot fireball created by a nuclear explosion, the temperature reaches several million degrees, evaporating everything. The fireball expands rapidly to maximum radius, which is determined by the yield of the nuclear weapon. In a nuclear explosion with the yield of the Hiroshima A-bomb, the fireball will inflate to a radius of about 140 meters in 1 second. As was mentioned in 2 above, the temperature of the fireball gradually cools as it expands and the fireball creates electromagnetic waves of different wavelengths. In this process, an extremely powerful visible light (light flash) and infrared rays (thermal radiation) are emitted. The intense light flash often referred to in Japan as “pika” will impair the sight of most people who look at it directly with the naked eye. The thermal radiation rapidly raises the temperature near ground zero, causing the first to fourth degree burns to the human body and igniting combustible matter, triggering fires. In some cases, the high

[20] The boundary value at which the effect emerges

temperatures resulting from a conflagration may create an updraft that lowers atmospheric pressure in that area. Surrounding air then flows in as storm-force winds. Thus numerous fires ignited by the thermal radiation and blast-induced structural damage will join up to form a massive firestorm that will consume everything combustible in its path.[21]

The burns resulting from thermal radiation are either primary burns directly caused by the flash or secondary burns that are the result of burning garments or buildings. The severity of the burn is judged according to the affected area and its depth.

The depth of a primary burn is categorized according to the amount of heat energy required to cause it. For example, 2.0 cal/cm^2 (0.08 MJ/m^2) of heat from a 1-kt nuclear weapon will cause first degree burns (skin reddens or shows red patches)[22]. Second degree burns (blistering) require 4.0 cal/cm^2 (0.17 MJ/m^2). Third degree burns (ulcer, necrosis) require 6.2 cal/cm^2 (0.26 MJ/m^2). Fourth degree burns are characterized by charring.

To assess the amount of area affected by burns, "the rule of nines" is generally applied to adults. The total skin area of the body is thought to be 9% each for head, right arm, left arm, right leg (front), right leg (back), left leg (front), left leg (back), chest, stomach, upper back, and lower back. Plus 1% for hands, this totals 100%. Burns second degree or worse covering more than 20% of the body surface are fatal. Burns third degree or greater covering 15% or more of the body surface can be expected to produce burn shock[23]. This shock is due to matter separating from the necrotized tissue, causing a rise in capillary permeability throughout the body.

5. Damage from Electromagnetic Pulse and Other Effects

(1) Effects of Electromagnetic Pulse

When a nuclear weapon explodes, the released gamma rays and the atmosphere interact to emit a vast quantity of electrons, resulting instantaneously in an extremely powerful electromagnetic wave (electromagnetic pulse). This electromagnetic pulse incapacitates a wide range of electronic appliances by inducing a surge in electric current. Consequently, communications and control operations may suffer significant disturbance.

To illustrate, if a nuclear warhead explodes 500 km above Omaha, which is in the center of the 48 contiguous US states, communications equipment, power transmission systems, computers, and radar throughout the country will be directly hit by a rise in voltage a million times more powerful than lightning. All equipment will cease to function, which will mean that the gathering and communication of information required for disaster relief activities will confront severe difficulties.

Modern electronic devices are built of ultra-miniaturized silicon chips for a certain operating voltage. This makes them more vulnerable to sudden surges in voltage.

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[21] In the firestorm after the Hamburg air raid during World War II, storm winds arose that uprooted trees as large as 1 meter in diameter [32].

[22] The amount of heat necessary to cause a given burn differs according to the yield of the nuclear weapon. For the values used in this Report, see Appendix C, Table C-4.

[23] With a rise in capillary permeability, a large amount of blood plasma leaks out of the blood vessel, decreasing blood circulating within the organs, leading to progressive organ disorders.

The Pentagon’s advisory committee, the Defense Science Board, recommended in “Future Strategic Strike Forces” in 2004 that the USA should obtain electromagnetic pulse-hardened weapons. Furthermore, the US Government’s Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack submitted a report [34] on July 22, 2004 to the US House Committee on Armed Services that North Korea may develop an EMP weapon to disable the United States’ national electronic infrastructure. In Japan, the Ministry of Defence Technical Research and Development Institute has just conducted research on protection against EMP.

Therefore, when creating nuclear attack scenarios, in addition to casualties from thermal radiation, blast and radiation, the effects of electromagnetic pulse must be taken into consideration. In view of the fact that it is not possible at present to accurately assess the damage that would be caused by nuclear electromagnetic pulse, we need to be fully aware of the fundamental difficulties to be encountered in terms of information gathering after the explosion and communication of information relating to relief work, over and above the damage brought on by thermal radiation, blast and radiation. That is to say, we should realize that we cannot rely on any information gathering and relief activities that rely on electronic devices in or near the disaster zone. Above all, we must be especially aware of the fact that electronic medical devices play a vital role in delivering emergency medical services of today.

(2) Effects of Groundless Rumors

In a chaotic situation, rumors fly because of the lack of a reliable source of information. Such rumors may well push people into dangerous group behavior.

A recent example is the earthquake that hit the western coast of Fukuoka City on March 20, 2005. On April 20, the area was struck by its largest aftershock, after which, by word of mouth, through SMS text messages via cell phones and other means, the rumor circulated around Fukuoka Prefecture and other areas that a large quake was on its way. The Meteorological Office found it necessary to send out a message to the public warning against believing groundless rumors [35]. In Wakayama Prefecture, a rumor went around that a major earthquake was going to occur on November 3 the same year. The sale of emergency articles soared [36].

According to research into social psychology, groundless rumors become easier to spread as the “importance x uncertainty” factor increases. A nuclear attack is a grave matter of life and death, which means that the “importance” of related information is enormous. Furthermore, in the chaos following an attack, the electromagnetic pulse described in the preceding section would render electronic communication devices useless. The effect of this communication paralysis would maximize the “uncertainty.” Therefore, a community that has suffered a nuclear attack is in a state where groundless rumors are most likely to occur. This means that we must be prepared to see more damage than might be expected in a scenario assuming rational public behavior.

(3) Psychological Effects

When human beings encounter an unexpected and massive explosion and witness scenes from hell unfold in front of them, they manifest psychological disorders. Some will be stunned and unable to move. Others will run around in a state of agitation, while others will lose all memories of the past and lose themselves, wandering about aimlessly and helplessly. Many of the A-bomb victims of Hiroshima and Nagasaki committed suicide. The reasons were most probably grief and loneliness after losing their families, social oppression (prejudice against A-bomb victims), regret and guilt over a failure to offer assistance at the time of the explosion, anxieties about grave illnesses, and a general loss of the will to live because of the numerous misfortunes bound to befall them in future. Moreover, even after acute psychiatric symptoms were alleviated, a considerable number of people suffered flashbacks several years or even decades later. When they heard a large noise or saw bright light, their memories would flood in to cause breathlessness and palpitations. This state would continue, with this unrestrained anxiety and physical excitement filling them with the desire to flee or fight [37, 38]. A nuclear attack would definitely cause numerous casualties from post-traumatic stress disorder, which is likely to plague the victim the rest of his or her life.

(4) Social Effects on the Community and Individual Victims

A nuclear weapons attack would obviously destroy all economic and production infrastructure, including roads, railways, water and sewerage systems, bridges, communication facilities, schools, hospitals and public housing, but it would also destroy almost entirely the information required for public administration. The reconstruction of the affected community would confront unimaginable hardships.

Among other effects, a nuclear attack aggravates the vulnerability of the affected area to natural disasters. On September 17 and 18, 1945, Typhoon Makurazaki attacked Hiroshima, just 40 days after the A-bomb. As a result of the floods and landslides, some 2,000 people, mainly in Hiroshima Prefecture, were dead or missing. The bridges that had barely managed to remain standing were washed away. Railways, roads and buildings being cleared or restored were flooded. The reconstruction efforts literally went down the drain. A-bomb victims lost their remaining belongings to the rising waters or were flooded out of air-raid shelters and temporary housing. People seeking to return to Hiroshima from outside the prefecture had to be evacuated again. Thus, it must be remembered that any region destroyed by a nuclear attack will shoulder the burden of increased vulnerability.

The victims of a nuclear attack not only suffer the physical effects of radiation, blast and thermal radiation but also struggle with anxieties about genetic effects, exposure to social discrimination and prejudice, and "indeterminate complaints[24]" called "*genbaku buraburabyo*." They consequently encounter severe difficulties in working and even leading everyday life. This phenomenon has been amply demonstrated by the grim experiences of the A-bomb victims of Hiroshima and Nagasaki. Sixty-two years later, A-bomb victims are still filing lawsuits to obtain official certification as sufferers of *genbakusho* (A-bomb disease). This evidence clearly shows that a nuclear weapons attack will inflict physical, psychological and social hardships that will cause suffering for many decades.

[24] Patients complain of being unwell, but no clear cause is identified when tests are carried out.

Chapter 4: Estimate of Damage Caused by a Nuclear Attack

At 8:15 a.m. on August 6, 1945, a U.S. bomber flew over Hiroshima, dropped an atomic bomb, made a steep turn and flew away. According to atomic bomb survivor testimony, the sky suddenly lit up with a blinding flash of light, causing most people within a 2 km radius from ground zero to faint. When they regained consciousness, they found themselves in pitch darkness. As things around them gradually came into view, they saw world transformed: people lying dead under rubble, others unable to move and begging for help, others whose burned skin was peeling from their bodies, others injured by fragments of glass or other flying debris, and others blown to pieces by the blast. Hardly anyone had heard the sound of an explosion or felt the blast.

Outside the 2 km radius, after the flash, many had, as trained, covered their eyes with their hands or plugged their ears with their fingers, but they heard and felt the blast. Unaware of what had happened, they simply tried to escape from where they were. With no idea where to go, most survivors say they just followed others walking ahead of them. All over the city lay the bodies of those who had collapsed and died while fleeing. Crowds of victims headed for the outskirts, inadvertently preventing rescue teams from reaching the city center. Only those who managed to leave the city center and arrive at safe refuges on their own were saved by rescue crews. Some survivors say they were exposed to black rain.

What follows is a chronicle of bombing events.

Time	Event
0 sec	A-bomb dropped from an altitude of about 9,600 m, detonating 43 seconds later at an altitude of 600 m.
1/1,000,000 sec	Nuclear fission complete. During this millionth of a second, massive neutron and gamma radiation emitted. Temperature inside bomb rose to over 1 million degrees centigrade and the pressure to hundreds of thousands of atmospheres, leading to explosion.
1/10,000 sec	Fireball grew to about 14 m radius, temperature fell to about 300,000 degrees centigrade.
1.5/100 sec	Fireball grew to about 90 m; surface temperature dropped to 1,700 degrees centigrade, rising again later.
0.3 sec	Surface temperature of the fireball rose to 7,000 degrees centigrade.
1 sec	Fireball grew to its maximum size of about 140 m radius, while its surface temperature dropped to 5,000 degrees centigrade.
3 sec	Fireball had released most of its energy.
About 10 sec	Complete devastation of the city by blast. Fires ignited.
After 3 min	People see the mushroom cloud.
After 20 min	“Black rain” containing ashes from fires and radiation began falling in some locations.

* Based on references [29, 39, 40].

Sixty-two years after this tragic event, what would it be like if the same thing were to happen in Hiroshima today?

1. Conditions assumed for damage estimate

(1) Conditions and rationale

As Japanese citizens seeking total abolition of nuclear weapons, we deeply regret that we must assume the possibility of a future nuclear weapon attack. However, as long as nuclear weapons continue to exist, the possibility cannot be denied. Thus, if nuclear weapons are used, what types would be used and for what purposes? Would they be used merely as a means of intimidation? Or would they be used to destroy specific facilities as a military tactic? Or would the purpose be the all-out terrorist devastation of a city? In any case, the attacker would choose the target, timing, yield, and detonation altitude to produce maximum effects, depending on the purpose. Those who are attacked, however, cannot possibly foresee who would carry out a strike or for what purpose, let alone identify the target or the yield of the nuclear weapon used.

Given these circumstances, it was decided to estimate damages based on the four hypothetical cases below. The first case assumes the same conditions that actually took place 62 years ago, i.e., a bomb dropped over the same ground zero during the day on a clear summer (August) weekday. The second, third and fourth cases take into consideration the actual nuclear weapons possessed by nuclear nations. (See Table B-1 in Exhibit B.)

Table 4-1 Four Hypothetical Cases of Nuclear Weapon Attack

Mode	Yield	Detonation altitude	Type	Rationale
Air burst	16 kt	600 m	Atomic bomb	Selected for comparison with 62 years ago
	1 Mt	2,400 m	Hydrogen bomb	Selected to represent “large” nuclear weapons
Surface burst	16 kt	1 m	Atomic bomb	Selected for comparison with air burst
	1 kt	1 m	Atomic bomb	Selected to represent “small” nuclear weapons

For the surface burst, a nuclear weapon attack primarily from the ground (guerrillas, commandos, terrorists, etc.) is assumed. For the air burst, a nuclear attack from the sky (ballistic missile, aircraft) is assumed. A detonation altitude of 2,400 m for a 1-megaton weapon would maximize the range affected by the blast wave with that level of destructive power [41].

(2) Limitations in estimating damages

Detailed analysis of radiation from the Hiroshima and Nagasaki atomic bombs has been carried out jointly by Japan and the United States. Studies on the effects of radiation on human bodies have been conducted on a continuous basis, with a primary focus on Hiroshima and Nagasaki [28, 42]. Yet, these analyses and studies concern only the actual disasters that Hiroshima and Nagasaki suffered. If estimates are to be made for different yields of nuclear weapons or city structures, the only resources to refer to are “limited and summarized” data from U.S. nuclear tests and other relevant information released to date, the credibility of which has not been verified. Figures shown in this report represent damages predicted on the basis of the most conservative figures, allowing for a substantial margin of error. It should be noted, therefore, that damages could be somewhat smaller or several times greater than these estimates, depending on conditions.

For details, assumptions and premises related to the values that appear in the following sections, please see Exhibits C and D.

2. Damage estimates for the four cases

This section will describe the various effects of a nuclear attack that cause damage and the probable ranges, on the basis of which the evaluation of overall damage will be made.

(1) Initial radiation

Table 4-2 shows ranges of the effects of initial radiation for unshielded exposure (outdoor-open), exposure behind buildings (outdoor-shielded) and inside buildings (wooden and non-wooden buildings[25]). (See Exhibit C [pp. 91–92] for more on the topic of shielding.)

Today, the area around ground zero is crowded with reinforced concrete and steel-frame buildings. Many homes have also been rebuilt as non-wooden structures. As they did 62 years ago, these buildings will shield people from radiation.

However, these calculations do not take into account the dispersion of initial radiation in the atmosphere or changes in radiation angle due to ascent of the fireball. For this reason, even in areas not included in the range of effects determined by a simple shielding calculation, the chances of being exposed to initial radiation are significant, especially in the case of a surface burst. When estimating the risks of exposure to initial radiation, therefore, one should refer to the range for unshielded exposure.

The release of initial radiation begins with the start of a nuclear fission reaction, and most of it will have been released by the time individuals see the flash of light. For this reason, even if individuals take evasive action immediately after the flash, they will have already been exposed to radiation.

(2) Blast

Reference [31] presents a method of roughly estimating damage a given blast would inflict on buildings. Table 4-3 gives standards for damage caused by blast, and the major ranges of effects calculated using this method. (See Table 4-4 for the definition of damages.)

The ranges presented in Table 4-3 should be interpreted only as standards because the method generates ranges of effects only at a given detonation altitude.

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[25] In this report, buildings are divided into two categories: wooden and non-wooden, which include very sturdy reinforced concrete structures. Wooden buildings are assumed to be homes.

Table 4-2 Estimated Ranges of Effects of Initial Radiation

Classification		1 kt	16 kt		1 Mt
		1 m	1 m	600 m	2,400 m
Fatality rate 100%; 7 Sv and up	Outdoor-Open	1.1 km	1.5 km	0.9 km	0.9 km
	Outdoor-Shielded	—	—	0.4 km	—
	Indoor-Wooden	—	—	0.8 km	0.2 km
	Indoor-Non-wooden	—	—	0.6 km	—
Fatality rate 50%; 4 Sv and up	Outdoor-Open	1.1 km	1.6 km	1.1 km	1.3 km
	Outdoor-Shielded	0.2 km	—	0.5 km	—
	Indoor-Wooden		—	0.9 km	0.8 km
	Indoor-Non-wooden		—	0.7 km	—
A-bomb survivors; 0.01 Sv and up	Outdoor-Open	2.2 km	2.9 km	2.5 km	3.0 km
	Outdoor-Shielded	0.3 km	0.3 km	1.5 km	1.5 km
	Indoor-Wooden			2.3 km	3.0 km
	Indoor-Non-wooden			1.7 km	2.1 km

* See Table C-1 in Exhibit C for casualty criteria, and Tables D-1 to D-4 in Exhibit D for the number of casualties. Dashes ("—") mean that, outside the area engulfed by the fireball, initial radiation would not reach doses shown in the classification section because of the shielding conditions shown in Exhibit C (pp. 91–92).

Table 4-3 Estimated Ranges of Effects of Blast

Classification		1 kt	16 kt		1 Mt
		1 m	1 m	600 m	2,400 m
Ranges in which casualty rates are calculated		1.4 km	3.5 km	4.5 km	18.0 km
Time required to reach above ranges		3.4 sec	8.5 sec	11.6 sec	46.4 sec
Ranges in which windows are shattered		2.4 km	6.1 km	7.2 km	29.0 km
Wooden residences	Major damage	0.6 km	1.5 km	2.0 km	8.9 km
	Medium damage	0.8 km	1.9 km	2.5 km	10.1 km
Steel-frame office buildings	Major damage	0.1 km	0.4 km	0.5 km	2.5 km
	Medium damage	0.2 km	0.5 km	0.6 km	2.8 km
Reinforced concrete office buildings	Major damage	0.1 km	0.4 km	0.6 km	2.8 km
	Medium damage	0.2 km	0.5 km	0.7 km	3.1 km

* Ranges in which casualty rates are calculated are those in which the overpressure from the blast is at least 1 psi (6.9 kPa). (See Exhibit C [p. 93] and Tables D-11 to D-14 in Exhibit D.) Windows are assumed to be shattered in ranges in which the value of overpressure from the blast is at least 0.5 psi (3.5 kPa)[31]. The magnitude of damage to buildings was determined using the method shown in Reference [31].

Sixty-two years ago, an atomic blast leveled wooden buildings across an extensive area, leaving many victims crushed to death under collapsed buildings or trapped and burned alive in the ensuing fires. In reinforced concrete buildings, the blast shattered windows and blew through, devastating the interiors. Many inside the buildings were killed by the blast directly or by glass fragments or other flying objects. In many cases, however, individuals inside concrete buildings were spared from being crushed because the building did not collapse.

As mentioned above, the area around ground zero is now crowded with reinforced concrete and steel-frame buildings. Being far less likely to collapse than wooden buildings, it was assumed that these sturdy structures would provide the same protective effects as 62 years ago.

Nonetheless, present-day buildings have larger windows and lighter inner and outer walls. They also contain more office equipment, furniture and fixtures than were present in 1945. When shattered and blown by a blast, the glass and other objects could deal lethal blows, increasing the number of casualties. Therefore, it cannot comfortably be concluded that sturdy structures will dramatically reduce the casualty rate.

Where the blast is concerned, if individuals instantly throw themselves to the ground at the moment they sense the flash, casualties will substantially decrease, except in areas very close to ground zero. But this will require preparedness and training during peacetime. (See Tables D-11 to D-14 in Exhibit D.)

Table 4-4 Definitions of Buildings and Severity of Damage
(Source: Reference [31])

Type	Definition of damage	
	Severe damage	Moderate damage
Wooden buildings; residential type; 1- or 2-story	Frame shattered, resulting in total collapse	Wall frames cracked, roofs heavily damaged, interior partition walls blown down
Multistory steel-frame office building; 3- to 10-story; lightweight weak walls collapse easily; earthquake-proof structure	Frame severely distorted; incipient collapse	Frame moderately distorted, interior partition walls blown down
Multistory reinforced concrete office building; 3- to 10-story; lightweight weak walls collapse easily; earthquake-proof structure	Frame severely distorted; incipient collapse	Framework moderately distorted, interior partition walls blown down, concrete peels off to some extent

(3) Flash and thermal radiation

Table 4-5 shows ranges in which individuals suffer from severe burns when directly exposed to thermal radiation. These ranges may vary and, in actual exposures, individuals in slightly more extensive ranges are expected to suffer from severe burns. (See Table C-4 in Exhibit C for damage criteria and Tables D-11 to D-14 in Exhibit D for thermal radiation values.)

A surface burst would expose far fewer to direct heat than an air burst. Most individuals inside buildings would be shielded by their own and other buildings.

Table 4-5 Estimated Ranges of Thermal Radiation Effects

Classification		1 kt	16 kt		1 Mt
		1 m	1 m	600 m	2,400 m
Degree of burns	III	0.3 km	1.2 km	2.2 km	12.3 km
	II	0.4 km	1.6 km	2.8 km	15.0 km
Duration of thermal radiation emission		0.5 sec	1.9 sec	1.4 sec	8.7 sec

* See Table C-4 in Exhibit C for damage criteria and Tables D-11 to D-14 in Exhibit D for thermal radiation values. The duration of thermal radiation emission was calculated using the method shown in Reference [31].

Burns can be prevented to a certain extent by hats and clothing, though any cloth would ignite beyond a certain temperature. In summer, people tend to expose more skin and wear lighter fabrics than in other seasons, making them more vulnerable to thermal radiation.

The thermal radiation will reach the victims simultaneously with light, quickly causing burns. The duration of thermal radiation (time required to release 80% of thermal energy from a nuclear explosion) is 0.5 seconds for a surface burst 1-kiloton weapon, 1.9 seconds for a surface burst 16-kiloton weapon, 1.4 seconds for an air burst 16-kiloton weapon, and 8.7 seconds for an air burst 1-megaton weapon. Thus, most energy is released in an extremely short period of time. For instance, a 1-megaton weapon bursting in the air would release half of its thermal radiation in 1.4 seconds, by which time individuals out to at least 9 km away would suffer third-degree burns. The closer the victim is to ground zero, the greater the energy exposure and the shorter the time. Unless they are far from ground zero, victims would have no chance to mitigate damage by taking evasive action.

Meanwhile, light emitted from the fireball will cause a temporary vision loss (temporary dizziness, and retinal burn if the lens focuses the light) in a far more extensive area than the range in which burns would be produced. While strict estimates of the range in which vision loss would occur were not attempted, examples in Reference [31] indicate that the explosion of a 1-megaton bomb at an altitude of 10,000 feet (about 3 km) would cause 10-second-long vision loss at distances as great as 21 km from ground zero on a clear day. Retinal burns would result at locations as far as 53 km away from ground zero if the lens focuses the light. These effects can be expected to cause traffic accidents and other hazards in an extensive area.

(4) Fires

The thermal radiation from a nuclear explosion will ignite flammable materials. The destruction of buildings by the blast can trigger the ignition of gas and other flammable material, resulting in fires across an extensive area. It is impossible to make a meaningful estimate about the range in which fires would be expected because they would be subject to such a variety of conditions. Many buildings today are steel-framed or made of reinforced concrete, with various fire prevention measures and firefighting equipment, such as sprinklers, in place. However, once a blast breaks windows and blows away interior walls and doors, these buildings, except for their frameworks, would be gutted by fire as similar buildings were 62 years ago. It should also be noted that flammable materials, such as gasoline in cars on the streets, which were practically nonexistent in 1945, abound in Hiroshima today, another factor that could exacerbate fires.

In view of these possibilities, the estimate of the range in which major fires can be expected took into account the overpressure from the blast and the intensity of thermal radiation in the area completely burned 62 years ago (a radius of about 2 km). In the case of a surface burst, thermal radiation would be blocked by buildings and other structures, which could limit the extent of fires. In the case of an air burst of a 1-megaton weapon, the emission of strong thermal radiation over an extensive area could cause large-scale fires not only in urban areas but in surrounding mountains and forests as well.

Reference [43] shows equations used to determine approximate threshold values at which thermal radiation would ignite flammable materials found in cities. Table 4-6 contains these ranges.

Table 4-6 Estimated Ranges in Which Fires Are Expected to Occur

Classification	1 kt	16 kt		1 Mt
	1 m	1 m	600 m	2,400 m
Range of large-scale fires	0.3 km	1.1 km	2.0 km	7.9 km
Range based on Reference [43]	0.5 km	1.5 km	2.7 km	13.8 km

* Ranges of large-scale fires were estimated taking into account the overpressure from the blast and the intensity of thermal radiation in the area totally burned 62 years ago (a radius of about 2 km).

Sixty-two years ago, firestorms occurred in some parts of the totally burned area. While it could not be determined conclusively that a firestorm would occur in today's Hiroshima, the possibility remains and the danger should be properly understood. In the case of a high-yield nuclear weapon such as a 1-megaton bomb, the effects of thermal radiation would be extremely extensive, resulting in massive loss of life [44].

(5) Residual radiation

Residual radiation comprises:

- Radiation emitted from substances on the ground that became radioactive as a result of exposure to neutrons from a nuclear explosion, and
- Radiation emitted from radioactive fallout. Fallout includes fission products (radioactive materials after a nuclear fission reaction), unfissioned nuclear materials, and substances on the earth that have become radioactive as a result of exposure to neutrons. Particles of these radioactive substances would be first drawn up into the atmosphere and eventually land back on earth.

The effects of residual radiation differ greatly between an air burst and a surface burst.

① Air burst

In the case of an air burst of a 16-kiloton nuclear weapon (detonation altitude: 600 m), residual radiation emitted from substances that have become radioactive on earth would be observed at ground zero at varying levels for a substantial length of time. This would prevent rescue workers from entering a 500 m radius from ground zero for at least one hour after detonation [28]. Residual radiation is also expected to impede not only ensuing rescue operations but also the recovery operations that would follow. In practice, because various substances would become radioactive (even glass would turn radioactive [31]), on-site radiation measurements would be required to determine the quantities of residual radiation, the areas to be restricted, and the duration of restriction. For example, experts tested for chromosomal aberrations in the peripheral lymphocytes of survivors of the atomic bomb 62 years ago who were in basements near ground zero at the time of the explosion. They found four cases of survivors presumed to have been exposed to radiation of 0.9 to 3.3 Sv. This was estimated based on the severity of chromosomal damage found in the survivors’ peripheral lymphocytes.

Meanwhile, 62 years ago, radioactive fallout settled over an extensive area in the form of a black rain. Some survivors reported exposure to this black rain during evacuation and developed symptoms characteristic of atomic bomb sickness (nausea, hair loss, etc.) Unfortunately, however, because of the effects of fallout from nuclear tests later conducted by several countries, it was impossible to determine the fallout effects (areas affected and quantity) that resulted exclusively from the nuclear attacks on Japan. In the case of Hiroshima, the initial radiation dose was measured in the Koi and Takasu districts. However, it is difficult to make any blanket estimate of damage actually caused by the fallout. To do so would require accounting for numerous complex conditions such as the range of survivors’ movements, amounts of rainfall, the possibility of fallout intake into survivors’ bodies and more. The same holds true for damage caused by residual radiation from the above-mentioned radioactive materials created on the ground.

While it is impossible to determine whether a black rain will always accompany nuclear explosions, a similar kind of black rain would be expected to fall if fires occurred in the same weather as during the Hiroshima bombing.

The estimates are also about the same for an air burst of a 1-megaton nuclear weapon (detonation altitude: 2,400 m). However, the quantity of neutrons reaching the earth's surface would be lower than in the case of a 16-kiloton bomb, which accordingly would result in a relatively lower likelihood of substances on the ground becoming radioactive. Where radioactive fallout is concerned, although the possibility of it falling to the earth in the form of rain remains undeniable, its relative danger would be reduced because particles would be drawn up to higher altitudes.

② Surface burst

In the case of a surface burst, residual radiation, particularly from radioactive fallout, would cause damage across an extensive area.

If a surface burst of a 16-kiloton weapon took place (detonation altitude: 1 m), it is estimated that an area around ground zero would be engulfed in a fireball as large as 270 m in radius, producing a crater about 50 m in radius and about 21 m deep. In the case of a 1-kiloton weapon, the fireball would be about 90 m in radius, digging out a crater estimated to be about 17 m in radius and about 8 m deep. From the crater would emerge large quantities of earth and sand that had been exposed to massive amounts of neutrons and turned radioactive, which would then be combined with the fissile material and drawn up into the air with the rise of the fireball and mushroom cloud[26].

Among the particles of earth and sand drawn up into the air, larger particles would quickly land in an area around ground zero, while smaller particles would be suspended in the air as radioactive dust and carried by the wind. These would eventually fall on people to negative effect.

It is extremely difficult to predict where, when, and how much of this radioactive dust would accumulate. Generally, it is believed that this type of fallout would travel downwind from ground zero. However, because the mushroom cloud would rise to an altitude of several kilometers, factors such as wind direction varying with altitude, changes in wind velocity, and topographical features must be taken into account. In addition, as demonstrated by U.S. nuclear tests, this type of dust is not deposited uniformly in all areas but rather accumulates in much higher quantities in some locations than in surrounding areas.

If it rains, the rain may wash away the dust and limit the range of dispersion. In this case, however, the dust is expected to settle in even larger quantities.

Reference [31] contains a simple method for estimating the range of diffusion of radioactive fallout. Figure 4-1 shows results obtained with this method. These estimates assume a difference in wind direction between the earth's surface and midair to be 15 degrees and the average wind velocity to be 24 km/h.

Using this method, the diffusion range of radioactive fallout is depicted assuming a certain radiation dose rate one hour after explosion. The residual radiation (gamma ray) dose at each distance from ground zero is also calculated based on a dose rate one hour after explosion. Table 4-7 shows the dose of residual radiation from radioactive fallout for different dose rates one hour after explosion. These

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[26] According to Reference [31], this kind of radioactive fallout would be a major problem when a detonation altitude is within $180 \times W^{0.4}$ feet (within 166 m for a 16-kiloton weapon), with a margin of error being ±30%. Here, "W" stands for the yield of a nuclear weapon in kilotons.

estimates assume that the fallout would accumulate in all areas immediately after the explosion.

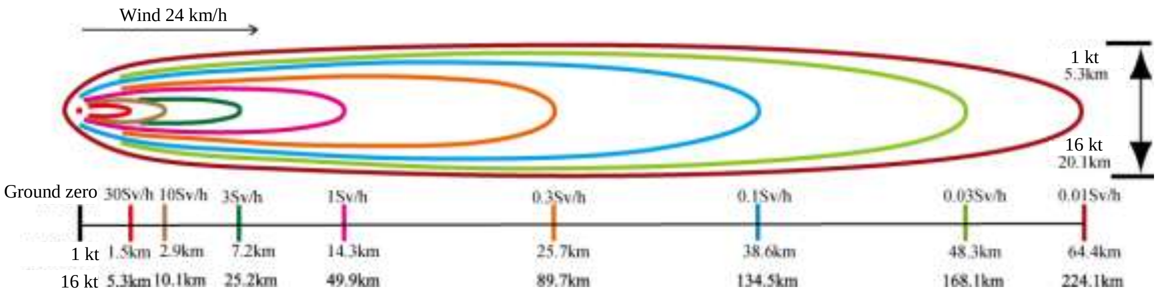

Figure 4-1 Results of Estimated Radioactive Fallout Diffusion Ranges and Dose Rates Determined by the Method Shown in Reference [31]

* Shown above are the results of an estimate of radioactive fallout diffusion obtained using the method shown in Reference [31], assuming a difference in wind direction between the earth's surface and midair to be 15 degrees and an average wind velocity of 24 km/h. In the case of a 1-kiloton weapon, the ellipse for the dose rate of 0.01 Sv/h one hour after explosion would spread to 64.4 km downwind, with a breadth of 5.3 km. In the case of the higher yield 16-kiloton weapon, the ellipse for the dose rate of 0.01 Sv/h would expand to 224.1 km downwind, with its breadth growing to 20.1 km. The dose rate of 0.01 Sv/h in this example is the dose rate one hour after explosion, and should be lower when the fallout actually reaches several dozens of kilometers away after traveling several hours. In this calculation, the data shown in Reference [31] has been converted to Sv.

Table 4-7 Residual Radiation Dose from Radioactive Fallout
(Residence Time and Accumulated Dose Based on Results in Figure 4-1)

Classification	Accumulated dose (gamma rays/Sv)					
Dose rate one hour after explosion	1 minute – 1 hour after explosion		1 min - 2 hrs	1 min - 4 hrs	1 min - 6 hrs	1 min - 12 hrs
	1 - 30 min	30 - 60 min				
30 Sv/h	131.14	22.31	172.98	189.72	198.09	209.25
10 Sv/h	43.71	7.44	57.66	63.24	66.03	69.75
3 Sv/h	13.12	2.23	17.30	18.97	19.81	20.93
1 Sv/h	4.38	0.74	5.77	6.32	6.60	6.98
0.3 Sv/h	1.32	0.22	1.73	1.90	1.98	2.09
0.1 Sv/h	0.44	0.07	0.58	0.63	0.66	0.70
0.03 Sv/h	0.13	0.02	0.17	0.19	0.20	0.21
0.01 Sv/h	0.04	0.01	0.06	0.06	0.07	0.07

* Estimated doses at an altitude of 1 m above ground determined by the method shown in Reference [31].

To calculate an expected radiation dose, the time required for the radioactive fallout to reach each specific location must be considered. According to Reference [31], the approximate time required for the radioactive fallout to arrive at a certain point can be determined by dividing the traveled distance by the wind velocity. In the case of a 1-kiloton weapon, for instance, since the ellipse for the dose rate of 0.3 Sv/h reaches 25.7 km downwind in about an hour, the expected radiation dose at that point can be determined by subtracting the dose during the initial one hour (the figure under "1 minute – 1 hour after explosion") from the dose in the "1 min – 2 hrs" column.

Data actually observed in U.S. nuclear tests are shown in Figure 4-2 for comparison with estimates in Figure 4-1. Although it is not realistic to draw a simple comparison between the two sets of data because conditions are different, it is at least possible to understand the difficulty of making accurate estimates. This is why it was decided not to make a casualty estimate in this report using the estimate method shown in Figure 4-1.

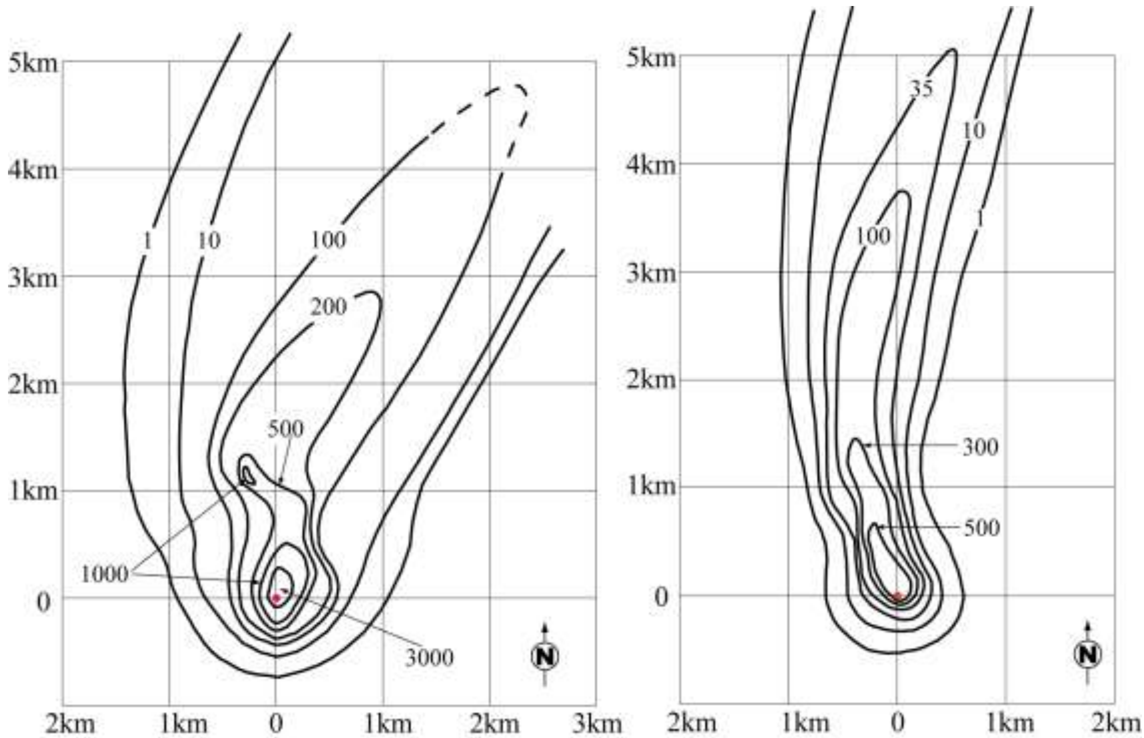

Figure 4-2 Radioactive Fallout Diffusion Ranges Observed in U.S. Nuclear Tests [45]

* Both weapons used for the tests had a yield of 1.2 kilotons. The detonation altitude was 5 m underground for the test shown in the left chart and 1 m above ground for the right chart. The difference in wind direction between the earth's surface and midair was 60 degrees at maximum for the left-side test, and 20 degrees at maximum for the right-side test. In the left example, a location with an extremely high radiation dosage when compared to its surroundings ("hot spot") is observed about 1.1 km north from ground zero. In the left chart, the dose rate of gamma rays one hour after explosion at an altitude of 1 m is indicated in R (roentgens), a unit of radiation dose. 1 R is equivalent to about 0.01 Sv of gamma rays.

(6) General Evaluation

① Air burst

Table 4-8 shows the estimated number of casualties resulting from an air burst. (See Tables C-15, C-18, C-23 and C-24 in Exhibit C for details.)

Today, with the increase of robustly built structures, initial damage, especially massive exposure to initial radiation or deaths due to building collapse, are likely to decrease dramatically. The estimation method used for this report assumes that the majority of citizens (approx. 3/4: See Table C-16 in Exhibit C) are inside such buildings at the time of the explosion, enjoying the protective effects of such buildings to the fullest extent. The figures in this report, therefore, should be interpreted as representing conservative damage estimates.

Table 4-8 Estimated Number of Casualties Resulting from an air burst

Yield			16 kt	1 Mt
Detonation altitude			600 m	2,400 m
Estimate results	Acute stage[27]	Deaths	66,000	372,000
		Injuries	205,000	460,000
		Casualty rate	46.4%	61.3%
	Aftereffects (Excess incidence[28])		A-bomb survivors: 155,000[29] Those developing leukemia/cancer: 13,000	A-bomb survivors: 46,000 Those developing leukemia/cancer: 1,000

* These estimates are based on several specific assumptions. See Exhibit C for these assumptions and estimate method.

(Reference) Estimates based on the method used in the example of damage estimates in [41]

Estimate results	Acute stage	Deaths	144,000	602,000
		Injuries	184,000	359,000
		Casualty rate	56.1%	70.7%

* These figures are provided to illustrate how estimate results vary depending on assumptions and estimate methods. See C-15 and C-23 in Exhibit C for details.

Under these circumstances, it is evident that those who are unfortunately in the

27 "Acute stage" means a period up to 3 to 4 months after exposure.

28 In this table, in order to indicate how radiation exposure heightens the risk of incidence of leukemia/cancer, excess incidence cases are shown as the number of survivors suffering from aftereffects. The number of excess incidence cases is determined by multiplying the number of survivors by the difference between the incidence rate of leukemia/cancer among those exposed to 0.01 Sv or higher radiation and among those who were not exposed to radiation.

29 "A-bomb survivors" is defined as the (injured and uninjured) survivors who were exposed to an initial radiation of 0.01 Sv or higher.

vicinity of ground zero or those who happen to be outside and unshielded would not be spared the negative effects of the explosion. These individuals would be exposed to massive initial radiation before seeing the flash and, immediately after the flash, would suffer damage from the blast and thermal radiation. Even those who are lucky enough to be in robust buildings and spared the effects from the initial radiation and thermal radiation may be lethally harmed by shattered windows, inner and outer walls, and furniture and fixtures shattered and thrown about in the blast. In high-rise buildings where people usually move by elevator, elevators are expected to be out of operation due to destruction or electrical failure caused by the blast, leaving survivors rushing to the evacuation stairs. However, as demonstrated in the 9/11 attacks in the U.S., typical evacuation stairs are not designed for simultaneous use by people from all floors. In addition, furniture and fixtures scattered in building rooms are expected to become obstructions, possibly causing stampede fatalities. It would also be difficult to evacuate heavily injured individuals from middle and upper floors in situations where the effects of residual radiation limit the access of rescue crews from the outside. Even outside buildings, streets would be strewn with rubble from collapsed buildings and destroyed vehicles. Evacuation efforts would be enormously hindered if vehicles burst into flames, among other possibilities. Meanwhile, fires would break out in many places, leaving panicked evacuees fleeing in all directions. Some individuals may be exposed to residual radiation during evacuation, as well, by being exposed to or inhaling radioactive dust or ash on the ground, or by being caught in black rain.

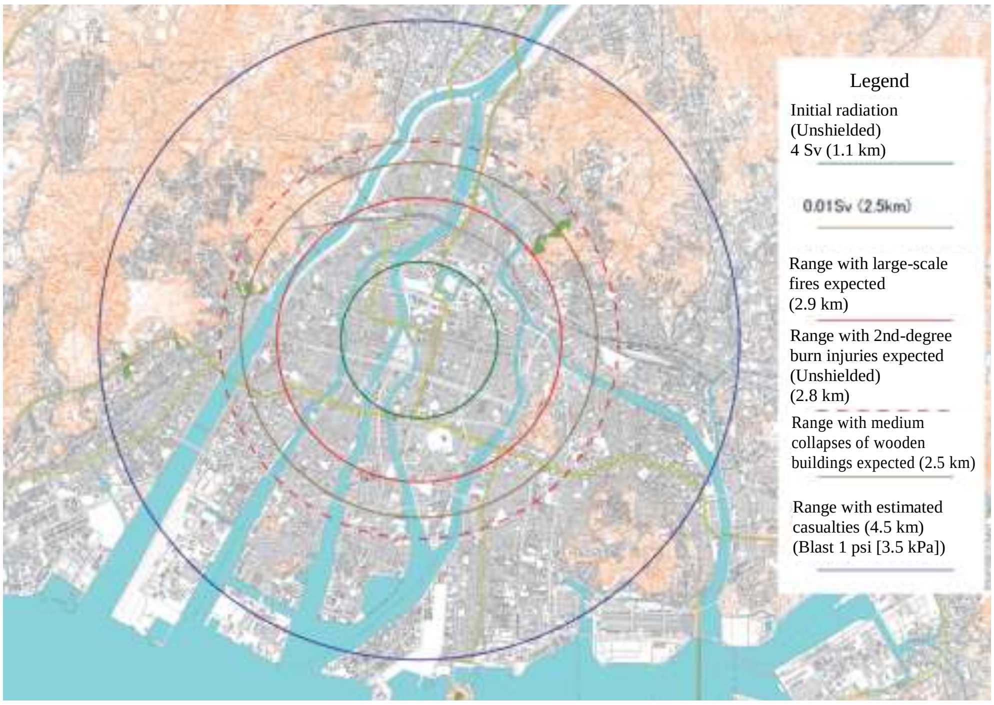

Figure 4-3 Ranges of Various Effects from the Explosion of a 16 kt Nuclear Weapon at an Altitude of 600 m

* Illustrated on the map are ranges shown in Tables 4-2, 4-3, 4-5 and 4-6. These are approximate ranges and not based on accurate distance measurements. The Digital Map 25000 (map image) “Hiroshima” released by the Geographical Survey Institute was used as a background map.

Taking into account all these effects, many of the estimated injuries would eventually result in deaths. For example, if approximately 1/3 of the injured individuals in an area where massive fires are expected to occur eventually perished, the number of fatalities would reach 100,000 for the explosion of a 16-kiloton weapon and 460,000 for a 1-megaton weapon. In the case of a 1-megaton weapon, there are estimates that predict a death toll of 800,000, placing major emphasis on the effect of fires. (See Table C-23 in Exhibit C.)

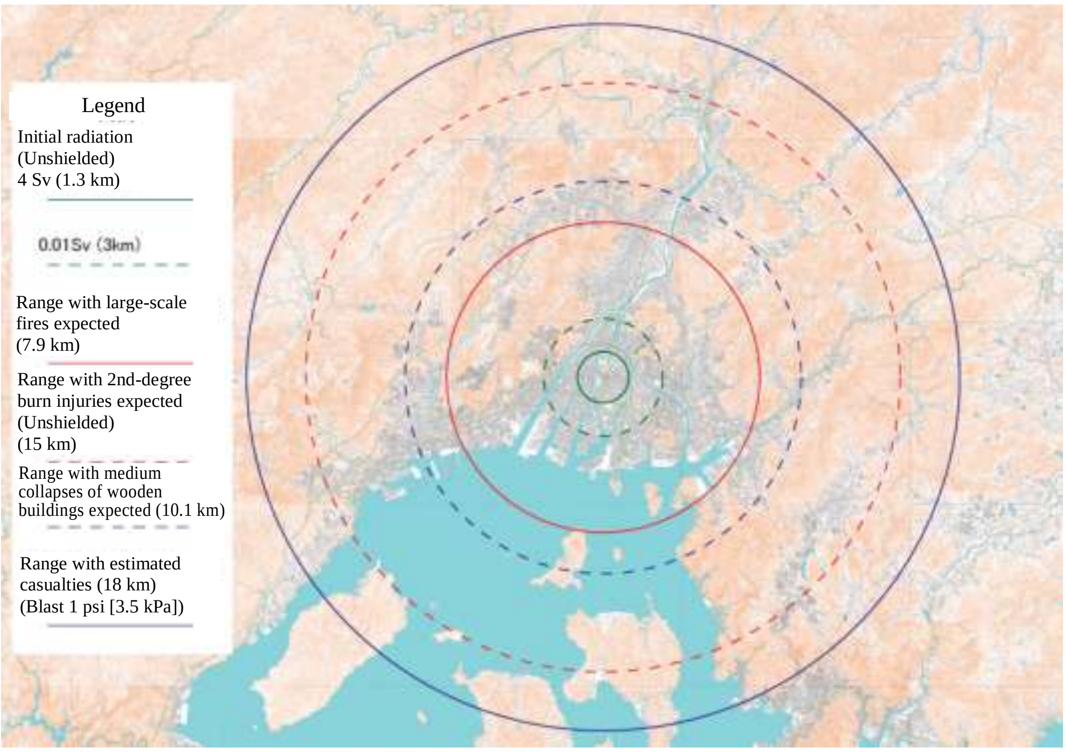

Figure 4-4　Ranges of Various Effects from the Explosion of a 1 Mt Nuclear Weapon at an Altitude of 2,400 m

* Illustrated on the map are ranges shown in Tables 4-2, 4-3, 4-5 and 4-6. These are approximate ranges and not based on accurate distance measurements. The Digital Map 25000 (map image) “Hiroshima” released by the Geographical Survey Institute was used as a background map.

② Surface burst

Table 4-9 shows the estimated casualties for a surface burst (detonation altitude: 1 m). These figures do not take into account the effects of nuclear fallout. (See C-28 and C-35 in Exhibit C for details.)

In the same way as an air burst, the data was obtained on the assumption that individuals would be able to enjoy the protective effects of robust buildings to the fullest extent, and therefore should be interpreted as representing the most conservative damage estimates. Also in the same way as suggested in [1] here, many of the estimated injuries would eventually result in deaths. Moreover, in actual situations, radioactive fallout is expected to be scattered over an extensive area, exposing a large number of individuals to residual radiation and its negative effects.

Table 4-9 Estimated Number of Casualties Resulting from a Surface Burst (excluding those affected by radioactive fallout)

Yield			1 kt	16 kt
Estimate results	Acute stage	Deaths	10,000	55,000
		Injuries	50,000	146,000
		Casualty rate	34.4%	43.9%

* These estimates are based on several specific assumptions. See Exhibit C for assumptions and estimate method.

(Reference) Estimates using the method used in the example of damage estimates in [41]

Estimate results	Acute stage	Deaths	15,000	99,000
		Injuries	55,000	141,000
		Casualty rate	40.4%	52.1%

* These figures are provided to illustrate how estimate results vary depending on assumptions and estimate methods. See C-28 and C-35 in Exhibit C for details.

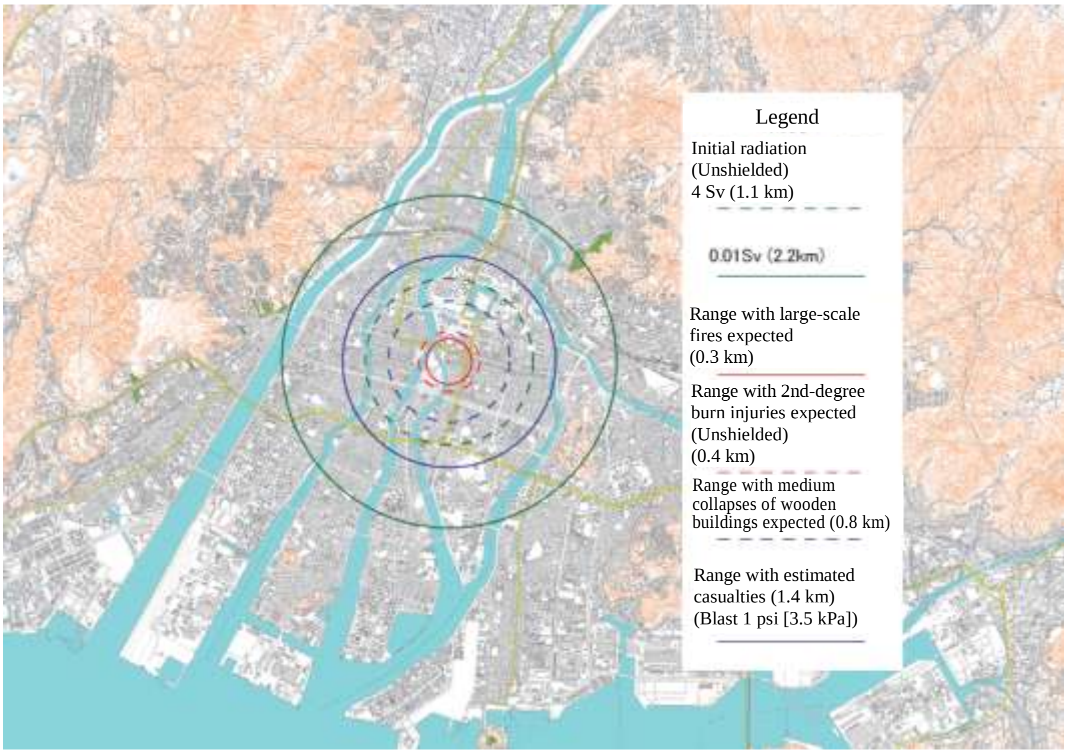

Figure 4-5 Ranges of Various Effects from the Explosion of a 1 kt Nuclear Weapon at an Altitude of 1 m

* Illustrated in the map are ranges shown in Tables 4-2, 4-3, 4-5 and 4-6. These are approximate ranges and not based on accurate distance measurements. The Digital Map 25000 (map image) “Hiroshima” released by the Geographical Survey Institute was used as a background map.

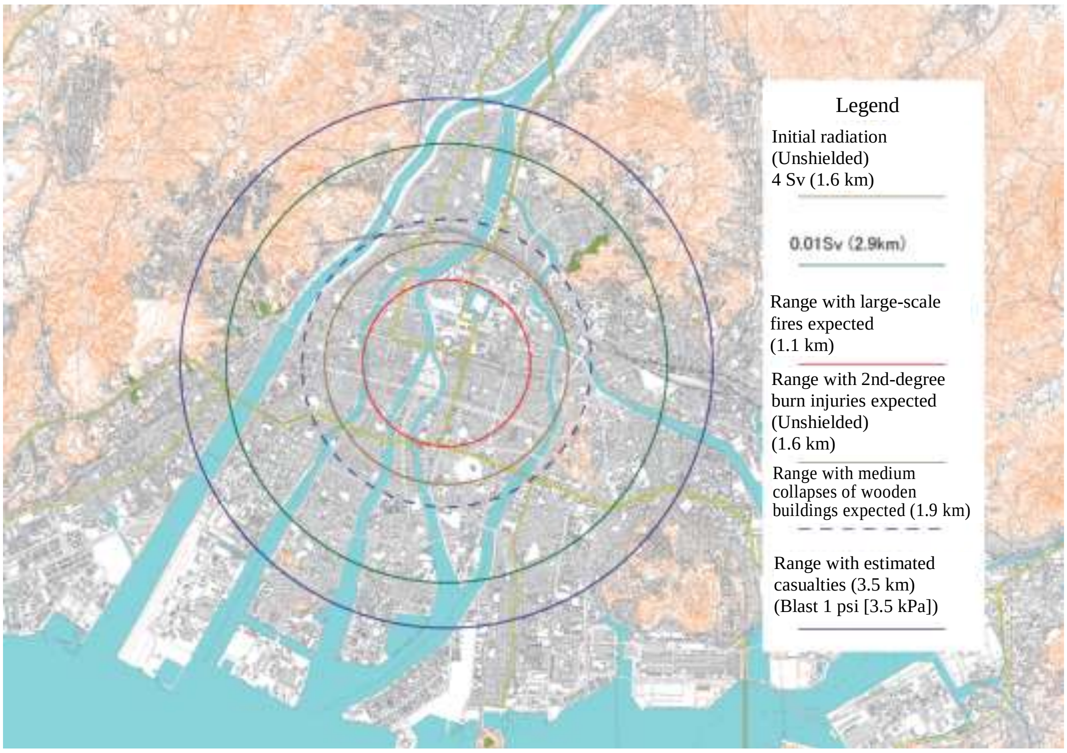

Figure 4-6 Ranges of Various Effects from the Explosion of a 16 kt Nuclear Weapon at an Altitude of 1 m

* Illustrated in the map are ranges shown in Tables 4-2, 4-3, 4-5 and 4-6. These are approximate ranges and not based on accurate distance measurements. The Digital Map 25000 (map image) "Hiroshima" released by the Geographical Survey Institute was used as a background map.

As mentioned earlier, it is difficult to estimate ranges of dispersion of radioactive fallout. Here, with the purpose of illustrating the threat of fallout, simple assumptions are proposed and shown in Table 4-10 to simulate its effects on humans. Table 4-11 shows the simulation results. (See Tables C-29, C-30, C-31, C-36, C-37 and C-38 in Exhibit C.)

As illustrated by the simulation results, radioactive fallout can cause enormous damage unless individuals find shelter indoors or evacuate in a timely manner.

In this simulation, it was assumed that radioactive fallout would settle in a certain limited area, but in actual situations, it is expected to spread throughout an extensive area, particularly in the direction of the wind. (Figure 4-7 shows examples of the extent of radioactive fallout diffusion.) It should also be noted that fallout particles, especially larger ones, would settle in all areas around ground zero, including those located upwind. Moreover, as shown in Figure 4-2, radioactive fallout can sometimes accumulate in much higher quantities in some locations when compared to their surroundings. In view of these factors, one cannot deny the possibility that there is an actual area in this world where the simulation results obtained on the basis of these assumptions could come true.

Table 4-10 Assumptions in Simulating the Effects of Radioactive Fallout

Classification	1 kt	16 kt
Exposure dose	As shown in examples in Reference [31], 60% of all radiation is expected to settle in a short period of time. Doses of gamma rays and beta rays were calculated on the assumption that half of such radiation would settle uniformly in a certain limited area 1 minute after detonation.	
Range of fallout diffusion	Within 1 km radius from ground zero	Within 3 km radius from ground zero
Survivors' behavior	The following three cases are assumed. • Start evacuation immediately after the explosion. • Take shelter indoors for 1 hour after the explosion, and start evacuation after that. • Take shelter indoors for 7 hours after the explosion, and start evacuation after that.	
Time required for evacuation	Uniformly 20 minutes	1 hour from ground zero to 1.5 km point; 30 minutes from 1.5 km point to 3 km point
Other	While taking shelter indoors, individuals are completely protected from residual radiation. During evacuation, individuals do not expose their skin, nor inhale any radioactive material, nor are they exposed to any effects of fires.	

* See Exhibit C (pp. 109 and 113) for individual assumptions.

Table 4-11 Simulation Results Concerning the Effects of Radioactive Fallout

Classification	1 kt	16 kt
Start evacuation immediately after the explosion	Deaths : 100,000 Injuries : 13,000 Aftereffects : 200	Deaths : 402,000 Injuries : 8,000 Aftereffects : —
Take shelter indoors for 1 hour after the explosion, and start evacuation after that.	Deaths : 55,000 Injuries : 58,000 Aftereffects : 15,000	Same as above
Take shelter indoors for 7 hours after the explosion, and start evacuation after that.	Deaths : 10,000 Injuries : 50,000 Aftereffects : 10,000	Deaths : 62,000 Injuries : 348,000 Aftereffects : 66,000

* Casualties in the above table were determined by incorporating the casualties in Table 4-9 with the effects of residual radiation based on the assumptions in Table 4-10.

This estimate assumes that individuals are completely protected from residual radiation while taking shelter indoors. Individuals are also assumed not to expose their skin nor inhale any radioactive material during evacuation. Yet, unless they manage to find evacuation sites that provide extremely high shielding against radiation, such as a basement, survivors are expected to continue being exposed to substantial amounts of gamma rays even while taking shelter indoors. Reference

[46] contains the standard shielding effects of various structures provided by the International Atomic Energy Agency (IAEA). Table 4-12 shows some examples of such shielding effects. From this data, at a minimum windows are expected to shatter within a 2.4 km radius for a 1-kiloton weapon, and within a 6.1 km radius for a 16-kiloton weapon, allowing radioactive dust inside buildings.

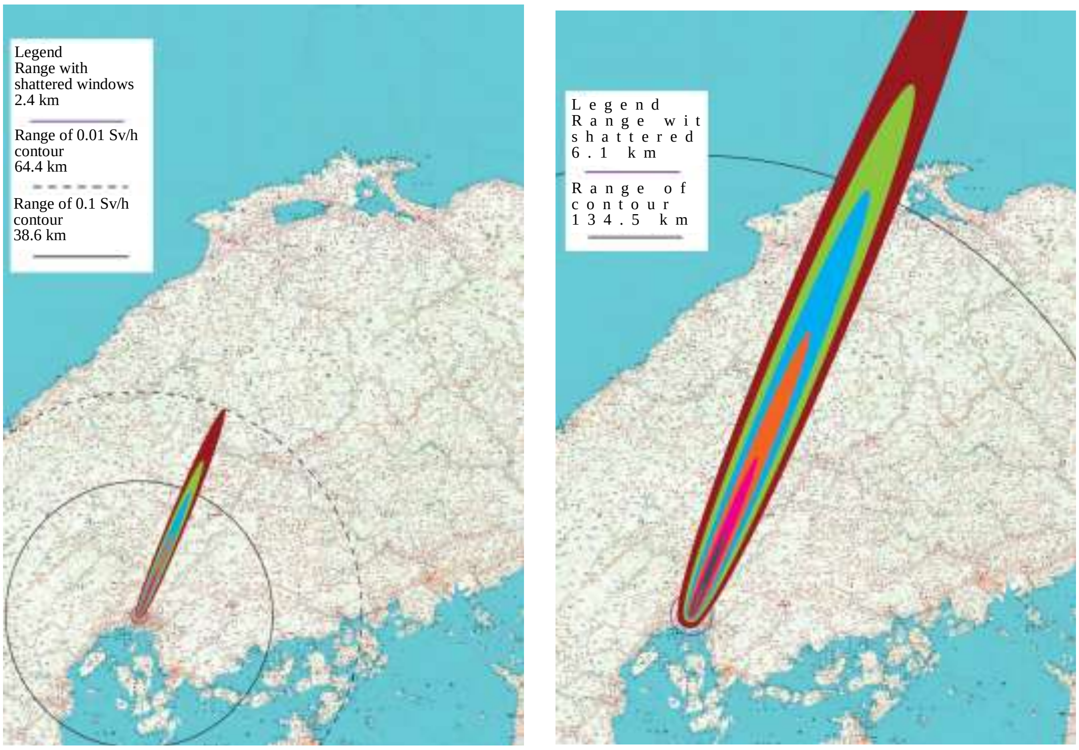

Figure 4-7 Ranges of Radioactive Fallout Diffusion Resulting from a Surface Burst

* Figure 4-7 expresses Figure 4-1 on the maps. The left map shows the fallout diffusion range for a 1-kiloton weapon, the right map for a 16-kiloton weapon. These are approximate ranges and not based on accurate distance measurements. The Digital Map 25000 (map image) "Hiroshima" released by the Geographical Survey Institute was used as a background map.

In addition, it is difficult in actual situations to completely avoid inhaling radioactive materials or exposing the skin during evacuation. In this context, beta rays (and alpha rays, as far as intake into human bodies is concerned) pose the greatest threat. In the case of a 16-kiloton bomb, for example, starting evacuation 7 hours after the explosion may prevent individuals from being exposed to the acute-stage effects of gamma rays. Still, beta rays would remain at a level that could cause severe radiodermatitis (a disorder similar to a burn injury, caused by prolonged exposure to radiation). When combined with other injuries, this could be fatal for some individuals.

Meanwhile, this estimate does not take into account the time required for the fallout to actually settle on the ground after the explosion. If one knows the fallout range and has enough time to escape, the best option is to evacuate outside that range. However, because radioactive fallout is believed to start settling on the area around ground zero 10–20 minutes after the explosion [47, 48], the closer the survivors are to ground zero, the fewer chances there are for them to complete evacuation in a timely manner.

Table 4-12 Reduction Coefficient for Exposure to Gamma Rays from Radioactive Materials

(Gamma rays from suspended radioactive materials)

Location	Reduction coefficient
Outdoors	1.0
Inside a car	1.0
Wooden house	0.9
Stone-built house	0.6
Basement of a wooden house	0.6
Basement of a stone-built house	0.4
Large concrete building (when away from doors and windows)	0.2 or less

(Gamma rays from deposited radioactive materials)

Location	Reduction coefficient
1 m above an idealized flat surface (unlimited space)	1.00
1 m above ground under normal land conditions[30]	0.70
1- or 2-story wooden house	0.40
1- or 2-story concrete block or brick house	0.20
The above’s basement	0.10 or less
1st and 2nd floors of 3- or 4-story building, each floor about 450–900 m^2	0.05
The above’s basement	0.01
Upper floors of a multistory building, each floor about 900 m^2 or larger	0.01
The above’s basement	0.005

Source: Reference [46]

③ Conclusion

On the day of the blast 62 years ago, 350,000 to 420,000 people were believed to be in Hiroshima [49]. Today, the daytime population in a 4.5 km radius from ground zero is estimated to be 580,000 (nighttime population: 450,000), much greater than at the time of the atomic bomb attack. While a smaller number of casualties than that of 62 years ago has been estimated for reasons already explained, it should be noted that figures in this report represent the most conservative damage estimates.

30 The reduction coefficient at an altitude of 1 m above ground under normal land conditions is assumed to be 0.7. In this report, shielding effects resulting from topographical features are not taken into account when calculating radiation doses, because actual shielding effects vary greatly depending on the surrounding environment.

A single 1-kiloton nuclear weapon, an “ultra-miniature” bomb by present-day standards, could result in human casualties exceeding that of the Great Hanshin-Awaji Earthquake; while a 16-kiloton weapon, which today falls in the category of “miniature” bombs, could produce extensive devastation comparable to that caused by the Great Kanto Earthquake. Another matter of concern is how to treat the vast number of injured survivors, including the many cases of minor injuries. According to the 2005 Survey of Medical Institutions conducted by Japan’s Health, Labor and Welfare Ministry, the number of general and convalescent beds, i.e., hospital beds excluding those for psychiatric, infectious disease and tuberculosis patients, is about 1.43 million nationwide and about 110,000 in the five prefectures in the Chugoku region. This is too few to provide the same level of medical care as in peacetime to such a large number of injured persons. In a nuclear attack, in particular, where injuries include not only trauma but also severe burns, radiation injuries and combined injuries, various types of medical expertise and treatment will be required. In the face of sudden loss of family members or the breakdown of infrastructure that has supported their livelihoods, many survivors may be tormented by memories of the nightmarish devastation and beset by an acute, indefinable malaise or depression. Even those who do not face these problems immediately will forever be faced with the possibility of developing them in the future. These possibilities alone attest to the unfathomable extent of the devastation resulting from a nuclear weapon attack.

Moreover, because a nuclear weapon attack is a nuclear disaster in which radiation affects nearly all aspects of life, enormous challenges can be expected from the time immediately after exposure through the periods of reconstruction and recovery.

3. Is it possible to mitigate casualties? — What damage estimates suggest

Based on the above damage estimates, several issues must be addressed regarding response to a nuclear weapon attack, or more specifically, the possibility of mitigating casualties. Mitigation measures include those carried out by individuals and those by administrative agencies, etc. First of all, steps to be taken by individuals will be examined. Then, challenges associated with measures to be taken by administrative agencies, etc. will be identified. Based on issues raised in this chapter, Chapter 5 will discuss in further detail whether the administrative agencies, etc. are really able to address these challenges.

(1) Individual responses

Guidelines on what individuals should do in the event of a nuclear weapon attack are provided in “Protecting Ourselves Against Armed Attacks and Terrorism,” a pamphlet released by the Government of Japan, as well as in other documents [47, 48, 50]. In this chapter, issues will be raised concerning individual response by referring to these documents.

① Reponses in the first minute[31]

If individuals are to avoid exposure to the effects of a nuclear attack during the first minute after the explosion, i.e., effects of initial radiation, blast and thermal radiation, the issuance of advance warnings by administrative agencies and other organizations are of the utmost importance. Aside from the specific length of time between the warnings and the explosion, warnings would at least give individuals chances to find shelter in rooms with few or no windows in robustly built structures, thereby significantly mitigating the injuries they might otherwise suffer during the first minute after the explosion. This possibility, of course, is based on the assumption that there are such buildings nearby.

Conversely, if there are no warnings, individual action would be very limited, only including such behavior as avoiding looking in the direction of the nuclear explosion, or ducking-and-covering on the ground or shielding themselves behind something when sensing a flash. With no warning, individuals would have no means to avoid the effects of initial radiation, eventually resulting in exposure to thermal radiation as well. In addition, since the blast wind takes longer to travel than radiation, individuals further away from ground zero would have more time respond to its effects. In fact, they could substantially mitigate the risk of being picked up in the blast by simply by throwing themselves to the ground.

Needless to say, individuals must be very well prepared if they are to execute these responses in an actual situation. Specific preparedness measures include: 1) checking in advance where to seek shelter in the event of an emergency at the workplace, school or home; 2) storing emergency supplies at each relevant facility; 3) collecting information concerning emergency protective actions against the blast; and 4) conducting drills of these actions as necessary.

② Responses after the first minute: Air burst

Avoiding the effect of residual radiation is essential after the first minute following a nuclear detonation. Effects of residual radiation differ greatly between an air burst and a surface burst.

In an air burst, because being closer to ground zero means greater effects of residual radiation on the ground, immediate evacuation would exacerbate rather than mitigate damage. Residual radiation would largely decay in the first hour. Thus, at least for the initial hour, survivors must avoid the effects of residual radiation by finding shelter in basements or other windowless locations (though the capacity of such places is limited), turn off the ventilation system and seal up windows and other openings to keep out dust. Afterwards, survivors need to evacuate places where they took shelter, avoiding exposing their skin and covering their mouths and noses (doing so would help reduce the danger of internal and external exposure to alpha and beta rays but not from gamma rays) and avoiding

[31] Although the initial effects of the blast and thermal radiation end within one minute, we decided to draw a line at the one-minute mark based on the definition of "initial radiation."

ground zero and the downwind direction[32]. If black rain falls, individuals should also avoid exposure.

Buildings are expected to be damaged to varying degrees (at least windows would be shattered), allowing in radioactive material. Fire is another factor that would pose a major threat. It would be impossible for survivors to determine the level of residual radiation by themselves. Devastation from the blast and the ensuing fires are expected to reduce visibility. Sixty-two years ago, many survivors fainted momentarily and when they regained consciousness it was pitch black. A mushroom cloud would also rise to a very high altitude. Wind direction is not always the same between the earth's surface and higher up in the sky. Moreover, in places where fires have started, the effects of the fires might change the wind's direction nearer to the earth's surface. If that happens, it would be even more difficult for survivors to identify the location of ground zero and the wind direction on their own. Some argue that survivors should head in a direction where damage seems less severe, but that could be hard to determine when visibility is extremely limited. Also, under these circumstances, it would be enormously difficult for individuals to accurately judge the situation around them and act in a composed manner. This is why peacetime preparedness and on-site guidance by administrative agencies, etc. are essential to ensure an effective evacuation.

Meanwhile, to prevent indoor shelters from being contaminated with radioactive material, individuals are recommended to take off their clothes and shoes if they have been outdoors, seal the clothes and shoes tightly in double plastic bags, and wash their bodies thoroughly with soap. While these are necessary measures to prevent secondary contamination, it would be difficult to actually take these steps in areas that have suffered enormous devastation.

③ Responses after the first minute: Surface burst

In a surface burst, radioactive fallout would spread over an extensive area, bringing about tremendous damage. In some areas, residual radiation could substantially exceed lethal dosages. In these areas, unless individuals can find nearby basements or other shelters with an extremely high shielding effect, they should promptly get outside the range of the radioactive fallout instead of taking shelter indoors. As mentioned earlier, in areas around ground zero in particular, the effects of radioactive fallout are said to manifest themselves 10 to 20 minutes after the explosion. Survivors need to keep in mind the same points during evacuation as in an air burst. Also, in areas where indoor shelters are believed to offer sufficient protection, survivors should note the same points as above when taking shelter indoors. The problem, however, is that it would be practically impossible for survivors to determine 1) the exact location of ground zero; 2) the wind direction; 3) the extent and pattern of the fallout; 4) whether to seek shelter indoors or to evacuate, and if they need to take shelter indoors, how long they should stay there; and above all, 5) whether the nuclear explosion was an air or surface burst. Unless administrative agencies, etc. promptly communicate this information to survivors

[32] It would be difficult for survivors to identify the detonation altitude on their own. Therefore, in the same way as in a surface burst, individuals are recommended to avoid being downwind when they evacuate.

and provide them with appropriate instructions regarding evacuation or indoor shelters, the spread of damage would be inevitable.

(2) Responses by administrative agencies, etc.

As previously discussed, in the absence of appropriate and quick response by administrative agencies, etc., individual action is extremely limited. While it is not clear what capabilities governments, etc. have at the moment or intend to develop in the future for taking appropriate responses, if the national government is to really commit itself to responding to a nuclear weapon attack, it should attempt the following regardless of achievability.

① Detect nuclear weapon attacks in advance and issue warnings immediately.

It would be understandably difficult to detect whether an attack was being carried out with a nuclear weapon or not. However, detecting in advance what is believed to be a nuclear weapon attack and then immediately issuing warnings could mitigate to a certain extent the effects during the first minute after the explosion. To this end, the national government is currently developing a system (called J-Alert, an alarm system to provide instantaneous warnings throughout the country) designed to issue tsunami warnings, weather warnings and warnings on armed attacks and other threats that require immediate response, to all citizens instantaneously and simultaneously by means of the disaster prevention radio system already set up in cities, towns and villages.

② Predict the extent of damage immediately after a nuclear weapon attack and instruct citizens to evacuate outside dangerous areas or seek shelter indoors.

The damage estimates discussed above were made by assuming specific nuclear weapon yields and detonation altitudes. However, in reality, it would be practically impossible to know in advance what kind of attack would be carried out.

The distinctive mushroom cloud would eventually reveal that it was a nuclear weapon attack. However, to predict the range of fallout diffusion and level of residual radiation in areas around ground zero, one needs to immediately learn the yield and design of the nuclear weapon used, the location of ground zero, the altitude or depth of detonation, the height of the mushroom cloud, the local weather conditions, and more. In particular, determining the altitude or depth of detonation (whether an air burst, surface burst, or a subsurface burst) would be of critical importance in formulating mitigation plans, because the intensity of residual radiation varies greatly depending on the altitude the weapon was detonated. Even if the detonation altitude is determined, however, it would remain difficult to accurately predict the range of fallout diffusion.

③ Deploy radiation measurement equipment, shielding materials and a substantial number of trained personnel in affected areas.

Apart from estimates in the above sections, real-time measurement of radiation doses needs to be carried out on-site. Based on the measurement results, rescue operations should be conducted, restricted areas should be set up, and decisions should be made on whether to instruct citizens to seek shelter indoors or to evacuate. However, because Hiroshima City has no nuclear-related facilities within the city borders, it has no sufficient stock of relevant equipment and supplies, and so would have to wait for its provision from neighboring prefectures. The same holds true for protective suits, protective masks and dosimeters that emergency responders need to wear. What emergency responders could do before they were provided with necessary emergency kits and gear would be very limited.

Moreover, unlike other types of disasters, emergency responders need to have specialized training. Also, a substantial number of emergency responders must be deployed because they would be required to carry out many different tasks: rescuing survivors, guiding evacuees in the right direction, setting up restricted areas, decontaminating affected individuals, and so on. It should also be noted that each individual emergency responder would only be allowed to work within the radiation dose limit specified for such an emergency.

④ Promptly establish a system to prevent the spread of radioactive contamination. Radioactive contamination spreads by two means. One is by entry into contaminated areas resulting in proximal exposure. Another is through radioactive materials attached to clothing and other items worn by survivors who have evacuated the contaminated areas.

With respect to contamination by entry into contaminated areas, the only possible means of prevention is to restrict all areas believed to be dangerous until actual radiation measurement becomes possible and rescue workers are provided with protective suits and protective masks. At this point, restricted areas should be demarcated again to allow for controlled entry. This means that, until residual radiation decays to a certain level, it would be impossible to rescue individuals, except for those who have managed to evacuate contaminated areas on their own. In the event of radioactive fallout from a surface burst, however, the above-mentioned approach would pose additional challenges because it would be impossible to judge whether it was believed dangerous until estimates were presented with reference to ranges of fallout diffusion.

Meanwhile, where radioactive materials attached to clothing and other items worn by survivors are concerned, decontamination measures should be taken to prevent the spread of contamination outside the restricted areas. Although uninjured individuals could decontaminate themselves by removing their clothing and showering, setting up decontamination facilities capable of accommodating thousands of survivors and treating water used for washing off contaminated materials remain open issues. Moreover, showering or washing would not be an option for those who suffer from trauma or burn injuries. With these survivors, there would be no choice but to provide them with medical treatment and decontamination measures simultaneously, either at a separate facility set up on-site or at a medical institution. In this situation, precautions should also be taken to prevent secondary contamination of medical staff involved in on-site triage (prioritizing patients), medical institutions that provide treatment to these patients, and personnel and equipment engaged in transporting survivors to the medical institutions. In the event that individuals have absorbed radioactive materials into their bodies, special medicine would be necessary to encourage the discharge of said material. Storing and transporting such medicine would be another issue that needs to be addressed. It would also be essential to disseminate this kind of specialized knowledge to medical experts[33]. The number of patients needing treatment is estimated to reach the tens of thousands.

Dead bodies exposed to high doses of neutrons would also become radioactive. Some bodies could also be contaminated with radioactive dust. Treating these contaminated bodies would be another issue of concern.

The blinding flash from the explosion, power failure and confusion are expected to cause traffic and other accidents, resulting in a substantial number of indirect injuries. Coordinating treatment of these injured individuals alongside survivors exposed to radiation would be another major issue of concern.

Regarding reconstruction efforts, it would be difficult for some time to access areas contaminated with radioactive fallout. Massive quantities of fallout is expected to accumulate in the area around the crater, among other locations, making it impossible to enter the area at least for a year. Needless to say, measures must be implemented to prevent such fallout from being diffused by wind and rain, resulting in the further spread of contamination. If prevention is impracticable, a large area subject to the spread of contamination would have to be sealed and constantly monitored.

⑤ Formulate measures in advance to evacuate a large number of citizens in a short time.
In a surface burst, in areas exposed to high doses of residual radiation resulting from the spread of radioactive fallout, individuals need to evacuate the areas rather than seek shelter indoors, except in cases where they can secure shelter that offers extremely high shielding effects. The time survivors have to evacuate these affected areas, however, is very short. Even if the range of fallout diffusion is predicted immediately after the explosion and evacuation orders are issued accordingly, it would be an enormously difficult task to evacuate a huge number of citizens in such a brief period of time. Evacuation by family car is dangerous because cars provide only limited shielding. Furthermore, there would be no way out if a cloud of radioactive fallout remained hanging over crowded streets. Needless to say, all individuals suspected of having been exposed to fallout to whatever extent during evacuation would have to be decontaminated.

⑥ Establish a chain of command and secure a means of communication in affected areas.
Telecommunication equipment in areas around ground zero is very likely to be destroyed or disabled by the blast and the resultant power failure, as well as by the electromagnetic pulse. The effects of residual radiation would restrict access to these areas. Some means of communication must be secured in advance to cope with this kind of situation. It should also be noted that communication would be made even more difficult if the effects during the first minute after the explosion

[33] Based on the report "The Role of Radiation Emergency Medicine" (Nuclear Safety Commission, June 2001) as well as on the national Basic Disaster Prevention Plan (Nuclear Safety Measures) revised in response to said report, efforts are underway to develop and enhance a radiation emergency medical service system and network comprising: 1) a primary care system catering to outpatients, 2) a secondary exposure care system providing hospital treatment, and 3) a local-level tertiary exposure care system providing specialized hospital treatment. Hiroshima University has been designated as a tertiary exposure care institution in western Japan.

disabled the functioning of Hiroshima Prefecture and Hiroshima City, agents expected to play central roles in implementing on-site emergency measures.

As discussed so far, it would be imperative for administrative agencies, etc. to formulate a detailed emergency response plan for a nuclear weapon attack, deploy necessary equipment and supplies, conduct drills, and communicate to citizens the kinds of preparation they should make, how to act in the event of emergencies, and how far administrative agencies, etc. are able to respond to these emergencies.

Chapter 5 discusses the possibilities, difficulties and other aspects of these emergency responses.

Chapter 5: Responses to a Nuclear Weapon Attack Disaster

1. Considerations in studying emergency responses

All members of this working group share the view that it is impossible to formulate any effective measures against a nuclear attack on a big city. In light of the experiences of the atomic bomb attacks on Hiroshima and Nagasaki, it is apparent that no disaster mitigation measures can do more than slightly alleviate the extent of the damage.

Despite the above-mentioned common understanding, a decision was made to examine possible responses to damage caused by a nuclear attack in the hope of demonstrating that even best possible measures could have very limited mitigation effects. To hold substantial discussions on how to respond to a nuclear weapon attack, one must imagine an extremely cruel scenario so forbidding that it makes one hesitate to even discuss the topic. Yet, if it is concluded that even the best possible responses would not be enough to prevent the worst case scenario, this conclusion is believed to enhance the persuasiveness of the argument for the total abolition of nuclear weapons. This is the main reason for studying possible responses to disasters resulting from a nuclear weapon attack.

The following three types of references are important when examining responses to disasters resulting from a nuclear weapon attack.

The first type of literature includes the histories of responses implemented in nuclear disasters that actually occurred in the past. Literature on measures against nuclear disasters performed by Hiroshima and Nagasaki, among other reference materials, provides many lessons concerning specific emergency responses. Numerous lessons can be learned from the experiences of responses to disasters associated with the civilian use of nuclear energy, i.e., nuclear power generation. Events of particular importance include, among other disasters, the explosion of Reactor No. 4 and ensuing fire at the Chernobyl Nuclear Power Plant in Ukraine, Soviet Union, in April 1986; and the criticality accident at the uranium processing plant in Tokai-mura, Japan, in September 1999 operated by the Japan Nuclear Fuel Conversion Co. (JCO), a subsidiary of Sumitomo Metal Mining Co.

The second type of literature is documents comprising reports on various scenario analyses and simulations conducted in the U.S. While the discussions in these documents are not necessarily comprehensive, they often contain noteworthy arguments.

The third type of literature is references that include laws regarding radiological protection and responses to radiation accidents. The Nuclear Disaster Special Measures Law (hereinafter, “The Nuclear Disaster Law”), among other laws, which describes emergency responses to nuclear disasters relating to civilian use of nuclear energy, is of particular importance. Also important are related laws such as implementation ordinances and regulations[34], as well as manuals drawn up by administrative agencies based on the Nuclear Disaster Law. The Nuclear Disaster

[34] All these documents are contained in “The Guide to the Nuclear Disaster Special Measures Law” (written and edited by the Society for Studies on Laws and Regulations Concerning Nuclear Disaster Prevention, Taisei Publishing Co., 2000).

Law was put into effect in 2000, its drafting commencing shortly after the commotion from the JCO criticality accident settled down. Being the only law spelling out disaster mitigation policies to be implemented under situations involving the spread of massive quantities of radiation, it would be useful for examining emergency response plans in light of the procedures stated in the Nuclear Disaster Law.

However, there is no scenario that portrays the actual implementation of response plans in combination with a specific depiction of a severe accident. Most discussions in relevant documents focus entirely on the necessary kinds of emergency response systems and how to establish them. It is tacitly agreed in this area of study that discussions on emergency measures should rule out the possibility of major disasters at civilian nuclear facilities that could endanger large numbers of local residents and cause heavy casualties [51]. This tendency is clearly reflected in the government's attitude toward the estimate of disasters resulting from armed attacks and nuclear disasters. For example, as part of the implementation efforts of the Civil Protection Plan, an anti-terrorist-attack drill was conducted on November 27, 2005, at the Mihama Nuclear Power Plant in Fukui Prefecture operated by Kansai Electric Power Company. The drill was carried out on the assumption that local residents would not be exposed to radiation. It is suspected that one reason why the government would not make disaster estimates or formulate specific response plans associated with such estimates is that such estimates or plans suggest the possibility of catastrophic disasters at civilian nuclear facilities.

Based on the responses specified in the Nuclear Disaster Law, lessons from past experiences in responses to nuclear disasters, and laws concerning radiation protection, this chapter will discuss the best possible responses to disasters by dividing a nuclear weapon attack into two stages:

First stage: Before the commencement of a nuclear weapon attack

Second stage: After the commencement of a nuclear weapon attack

Based on these discussions, it will be demonstrated that even the best possible policies can do nothing but slightly mitigate the disaster, thereby suggesting that the protection of the life and health of citizens is not compatible with the use of nuclear weapons.

The reason for referring to the Nuclear Disaster Law in these discussions is that there are no other laws that can be used as a basis for producing a specific scenario. In Articles 105 and 106 of the Civil Protection Law, there are provisions concerning responses to a nuclear disaster resulting from an armed attack on a nuclear power facility. But these provisions were formulated on the basis of what is specified in the Nuclear Disaster Law, with some modifications added to incorporate factors unique to situations involving armed attacks, etc. In addition, Articles 107 to 110 of the Civil Protection Law contain provisions on the prevention of the spread of contamination by radioactive materials, etc. (including chemical weapons and biological/toxic weapons). While these provisions are also applicable to nuclear weapon attacks, their specific contents are no more than checklists enumerating matters to be considered.

Before going into the main part of this chapter, it should be noted that there are significant differences between nuclear weapon attacks and accidents at civilian nuclear facilities such as nuclear power stations.

A nuclear weapon attack would instantly cause a vast number of casualties in unpredictable locations. It is also highly likely that such an attack would be targeted at a densely populated area. Deaths of residents would be caused by exposure to radiation, the blast, and thermal radiation. These effects would affect human bodies in a combined manner. In many cases, a nuclear weapon attack would be followed by massive fires (in some instances firestorms). The attack would also cause the instantaneous destruction of lifelines, including telecommunication and transportation infrastructure. Such destruction includes the paralysis of telecommunication and electric power systems caused by the electromagnetic pulse. In the most extreme scenario, disasters could be caused by several attacks carried out on several targets either simultaneously or consecutively, i.e., the possibility of synchronized multiple attacks or staggered multiple attacks.

In contrast, civilian nuclear facility accidents, no matter how massive they might be, would occur at certain predictable locations distant from population centers (because of remote siting), resulting in relatively few acute casualties. Deaths and injuries of residents would be caused mainly from radiation exposure, except for accidents during emergency actions, because there would be no blast or thermal radiation involved. There would be no serious damage to lifelines, either. Also, it is extremely unlikely that several severe accidents occur simultaneously at different locations in Japan.

Because of these differences, estimating damage caused by a severe accident at a civilian nuclear facility, provided that it happens in isolation, is much easier than estimating the damage resulting from a nuclear weapon attack. The same holds true for disasters caused by an armed attack on a nuclear power station, etc. It is believed that an attack on such a facility would be carried out with conventional weapons rather than nuclear. If nuclear weapons are used at all, a direct attack on the center of a major city is usually much more likely to cause more extensive casualties and damage. Still, depending on the conditions, there would remain the possibility of a nuclear weapon attack on a civilian nuclear facility. Coping with a nuclear weapon attack on a civilian nuclear facility would be a relatively simpler challenge in that the explosion is unlikely to happen in a densely populated area. Where radiation is concerned, however, emissions from the civilian nuclear facility added to radiation from the weapon itself would make emergency responses enormously difficult. Meanwhile, in the case of a civilian nuclear facility accident resulting from other disasters such as a huge earthquake (known as *genpatsu-shinsai*, the combination of an earthquake and nuclear meltdown), telecommunications, transport and various other lifelines are expected to be destroyed, making emergency response even more challenging than in the case of a severe accident happening in isolation.

2. Radiological protection standards

Before discussing responses to a nuclear weapon attack, a minimum outline will be provided with respect to radiological protection standards.

Current radiological protection standards, contained in the national law promulgated in 2001 in accordance with the 1990 recommendation of the International Commission on Radiological Protection (ICRP), stipulate as follows: (In the interest of simplicity, only data concerning whole-body exposure will be cited.)

Radiological protection standards are divided into two categories: those for normal times ("normal time" is not a legal expression but indicates instances excluding emergencies) and those for emergencies. The normal-time (effective) dose limit is 20 mSv a year on average over 5 years for occupational exposure (exposure allowed for radiation workers specified by law). Within this limit however, exposure of 50 mSv a year is permissible. The dose limit for public exposure (exposure allowed for individuals excluding radiation workers) is 1 mSv a year.

In emergency situations, different standards apply. For instance, the dose limit for disaster prevention officers (police officers, firefighters, members of the Self Defense Forces, etc.) is stipulated as 50 mSv in the case of emergencies, on the assumption that many disaster prevention officers are engaged in such operations as guidance and rescue of survivors. Furthermore, a dose limit of 100 mSv would be applied to these officers when they carry out operations that are urgent and required for lifesaving, preventing the spread of disaster, etc. For radiation workers, a dose limit of 100 mSv would be applied in the event of emergencies (even if no reason exists such as lifesaving or preventing the spread of disaster).

The 1990 ICRP recommendation specifies a dose limit of 500 mSv for disaster prevention officers in the event of emergencies. This limit was set on the basis of the experience during the Chernobyl accident but has not been introduced into Japan's relevant national law. While a dose limit of 500 mSv is below the lethal limit, it still involves the risk of acute radiation sickness. In view of the dangers that disaster prevention officers could be exposed to, raising the dose limit more than the present level is an unacceptable option. However, the above dose limit was not set as a standard for minimizing deaths in situations where many lives are at risk. Therefore, in emergency situations, it is possible that disaster prevention officers depart from the automatic and uniform observation of this dose limit and instead apply it in a more flexible manner.

The following doses are specified as reference standards for residents deciding whether to seek shelter indoors or evacuate in the event of a nuclear disaster. When the predicted external exposure dose is 10 to 50 mSv, residents are required to seek shelter indoors, seek shelter in concrete buildings, or evacuate, depending on the instructions given to them. When the predicted dose is 50 mSv or higher, residents must either seek shelter in concrete buildings or evacuate. In other words, the predicted dose of 10 mSv (equal to 0.01 Sv, the standard exposure dose for atomic bomb survivors as defined by this working group) is the minimum standard for issuing instructions. These are the standards for a "zone where an emergency response plan must be planned and carried out intensively" under the Nuclear Disaster Law (Emergency Planning Zone or EPZ), which in Japan is specified as an 8 to 10 km radius around a commercial nuclear power reactor. These standards are also expected to be applied in the case of a nuclear weapon attack.

The figures shown above are the standards for emergency situations and are applied to short-term shelter and evacuation. While Japan does not have any standards for decontamination of areas exposed to high levels of radiation -- standards that would require residents to relocate on a long term basis if levels did not drop -- a dose limit of 1 mSv per year for public exposure is believed to function as a useful criterion. In the Chernobyl disaster, a dose limit of 5 mSv/y was used as a criterion for demarcating a zone from which to relocate people. In the U.S., the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA) have issued stricter standards of 0.25 mSv/y and 0.15 mSv/y, respectively [52].

It would be extremely difficult to conduct activities such as disaster status investigation and rescue and guidance of survivors within the strict radiological protection standard of 100 mSv. Concerning areas within a several kilometer radius in particular, it would be impossible to even step into them for a significant period after the explosion, even if there were survivors to be rescued or other missions to be carried out. In the case of the surface burst of a 16-kiloton bomb as discussed in Chapter 4, it would be on the eighth day after the explosion that emergency responders would be allowed to work for one hour within a 3 km radius. (See Table D-5 in Appendix D. The value used for the simulation in Chapter 4 is 60% of the value shown in Table D-5.)

Nevertheless, although it is believed that individuals would begin to demonstrate symptoms of acute radiation sickness at 500 mSv or higher, they would still be able to function for a while even if their exposure exceeded that level. Moreover, the radiological protection standard of 100 mSv is not specifically based on the principle of minimizing loss of life. Therefore, it would be possible to implement these standards more flexibly in actual emergency situations.

3. First-stage responses to a nuclear weapon attack: Before the beginning of a nuclear attack

This stage comprises a period until the first nuclear weapon is detonated. This stage can also be divided into normal time and alert time.

The following three measures could be taken during normal time.

① Draw up and release a specific and detailed response plan.

② Based on the response plan, provide training/drills for disaster prevention officers and residents. To cope with nuclear disasters, special training/drills concerning radiation/radioactivity and measures against them are extremely important. Without such training/drills, any response plan would be utterly useless.

③ Based on the response plan, establish a local nuclear emergency response headquarters. Also, develop a network for radiation/radioactivity information collection and analysis. In addition, deploy personnel, supplies and equipment for nuclear disaster mitigation. These sorts of actions would be necessary for preparedness in response to a nuclear weapon attack in accordance with provisions in the Nuclear Disaster Law.

While ③ is not mentioned in the Civil Protection Law or its basic guidelines, if a nuclear weapon attack is assumed to be a realistic possibility, what is written in ③ should be implemented in all places besides areas around nuclear power stations, etc. The systems and facilities mentioned in ③ must be established in all cities that could be subject to nuclear weapon attacks. (In areas around nuclear power stations, etc., such systems and facilities are already in place and would suffice the way they are now.)

At an off-site center defined under the Nuclear Disaster Law, a Joint Council for Nuclear Emergency Response (i.e., local nuclear emergency response headquarters) will be organized and respond to emergency situations under the direction of a central government nuclear emergency response headquarters (headed by the prime minister). The off-site center will be located 8 to 20 km from the relevant nuclear facility. For the issuance of prompt and appropriate instructions, it is desirable to locate the off-site center close to a nuclear facility. But if too close to the nuclear facility, it would be directly exposed to the effects of radiation/radioactivity. This is why the distances above are specified. At the off-site center, officials from the central, prefectural and municipal governments would gather and issue instructions to the nuclear operator, police, fire department and Self Defense Forces. Transportation and telecommunications infrastructures would be built and radiation/radioactivity monitoring systems established. The facility would support the minimum functions required for exposure mitigation and decontamination, being of sufficient space to accommodate the required technologies. Concerning the chain of command, the Nuclear Disaster Law is based on a top-down system where the central government nuclear emergency response headquarters directs the local nuclear emergency response headquarters, which then locally directs specific response operations. The chain of command under the Civil Protection Law is based on this same idea.

With respect to equipment and supplies, Article 12 includes provisions regarding the Implementation Regulations of the Nuclear Disaster Law. Stipulations in these provisions include: 1) protective gear against radiation hazards (protective suits, protective mask, etc.), which are not very effective against external exposure but are effective against internal exposure, should be prepared for the number of disaster prevention officers, 2) more than the normally prescribed number of emergency telecommunications devices and other measuring instruments should be prepared. These equipment and supplies will naturally be stored in the nuclear operators' facilities.

If Hiroshima City determines that there is a realistic possibility of a nuclear weapon attack on the city, it would need to set up an organization comprising full-time expert staffers, and establish a command center that will contain a local nuclear emergency response headquarters which functions as an off-site center. While it would be hard to identify beforehand the target of a nuclear weapon attack, it is highly likely that the city center would be chosen as the target to maximize the effects of the nuclear weapon attack. Therefore, it would be necessary to build in redundancy by establishing a command center inside or in the vicinity of the city hall, and setting up a preliminary center in the suburbs 8 to 20 km away from city hall in case the city center were attacked. It would also be possible to build a preliminary center in an underground-shelter-type design to protect it from destruction.

Furthermore, to cope with the paralysis of electric power systems and the destruction of telecommunications systems that could be caused by the electromagnetic pulse generated by the nuclear explosion, it would be necessary to furnish the off-site center with emergency power-generating and telecommunications systems. Also, it would be necessary to establish an ERSS[35] (emergency rescue support system), which is usually set up at nuclear power plants, as well as a SPEEDI[36] (system for prediction of environmental emergency dose information), in a way that covers the entire city center. Regarding protective gear against radiation hazards (protective suits, protective mask, etc.), because at least thousands of disaster prevention officers would probably be necessary for relevant emergency response operations, sets of gear for at least that number of disaster prevention officers must be secured and stored at the preliminary center and other locations. (While it may be possible to transport some equipment or supplies by helicopter from a nearby civilian nuclear facility subject to prior consent of the civilian facility, it would not be a viable option when a large quantity of equipment and supplies is involved.) Another possible measure would be to redevelop an underground town in such a way that it could also function as a public nuclear shelter.

Because all these are very extensive measures, they could not be carried out by Hiroshima City alone, or by any other major city for that matter. These steps, if implemented at all, must be jointly carried out by all major cities in Japan with the central government taking necessary budgetary procedures under relevant laws. (Hiroshima is just another major city in Japan and, though it has a disturbing symbolic connection in the Japanese people's historical consciousness, the city is today no more likely than any other major city in the country to be a target of a nuclear weapon attack.)

At the moment, the possibility of a nuclear weapon attack on Japan is very low. Therefore, if Japan takes the above-mentioned measures, it would be viewed as an overreaction not seen anywhere else in the world. This kind of preparedness would not only be a waste of taxpayers' money but would also be regarded by the international community and neighboring countries as an action in preparation for nuclear war, possibly heightening military tension and eventually exacerbating the nuclear arms race and nuclear proliferation. In other words, implementing these measures would invite a situation similar to one in which a country tries to strengthen its nuclear capabilities to cope with a rival country's efforts to step up its missile defense system. Besides, as discussed below, taking into account that the effects of

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[35] "Based on information sent by electric power companies in the case of emergencies, including accidents, at a nuclear power station, this system monitors the status of the instruments at the relevant nuclear power station, determines the current status of the power station on the basis of a specialized knowledge database, and calculates and predicts by computer the future development of the accident." (Source: Ministry of Education, Culture, Sports, Science and Technology, "Disaster Prevention and Nuclear Safety Network for Nuclear Environment – Nuclear Disaster Prevention Glossary", http://www.bousai.ne.jp/visual/bousai_kensyu/ (in Japanese).)

[36] "In the case of emergencies that are expected or feared to result in the emission of a large quantity of radioactive material from a nuclear power station, etc., this system promptly predicts the environmental impact of radioactive material on the surrounding environment, such as radioactive concentration in the atmosphere and exposure dose, based on such information as the source of release of radioactive materials, weather conditions, and topographical data (ibid.)

disaster mitigation measures are extremely limited, all efforts directed at implementing these measures would be utterly futile.

For the same reasons, formulation of a specific and detailed response plan that assumes a nuclear weapon attack and implementation of special training and drills based on such a plan would be unnecessary.

Yet, it would be helpful for disaster prevention officers and ordinary citizens today to be educated and enlightened about nuclear disasters and responses to them, namely because nuclear facilities, especially nuclear power stations, are ubiquitous both in Japan and around the world. It would be essential for disaster prevention officers, who could be dispatched by order to any dangerous area at any time, to have a substantial amount of knowledge concerning nuclear disasters and responses to them. Moreover, a proposal has been made to establish and operate a simple radiation monitoring network on a nationwide scale with an eye toward mitigating extensive effects of civilian nuclear facility accidents. This network is believed to be very useful and could be utilized in the event of a nuclear weapon attack, as well [53].

If signs of a nuclear weapon attack are fortunately detected by means of satellite photographs, radar images, advance notice from the attacker, intelligence reports and the like, and warnings are issued accordingly enabling all concerned parties to go on alert, Hiroshima City could then take the following measures during the alert time.

If the above-mentioned robust emergency response systems were put in place during peacetime with comprehensive guidance and support from the national government, it would suffice to reexamine the system and prepare it for operation. This scenario, however, is quite unlikely in reality.

The more likely scenario in actual situations would be that a conventional system designed to respond to armed attacks would be activated. Though guidelines for implementing such a system contain virtually no provisions concerning proactive measures against a nuclear weapon attack, it would be possible to give residents such general instructions as moving from outdoors to indoors or, for those already indoors, taking shelter in basements or other windowless rooms, when an explosion is believed to take place soon. If it is believed that there is a certain length of time before an explosion, it would also be possible to evacuate the great majority of the population from the city center.

However, unless a situation is avoided where the great majority of citizens remain in the city and are exposed to the explosion, the effects of any proactive measures would be very limited. Although it would be a different story if the great majority of the population managed to evacuate, it would again be unrealistic to call for evacuation from all major cities in Japan when the targets of a nuclear weapon attack are unknown and when the chances are hard to estimate. Doing so would invariably lead to a protracted, complete paralysis of economic activities in Japan. Thus, steps that could be taken would be limited to: 1) issuing danger warnings, 2) evacuating pregnant women and infants to locations outside the city that are distant from military bases, etc., 3) calling on other individuals to refrain from engaging themselves in outdoor activities or staying in the city center unless such activities or stay were urgent or unavoidable, and 4) calling on officers and crews expected to play a central role in disaster prevention operations to move as much as possible to places less likely to be an object of destruction by a blast, such as basements or windowless rooms with thick reinforced concrete walls. Any responses that go beyond these steps would be impracticable.

4. Second-stage responses to a nuclear weapon attack: After the commencement of a nuclear attack

This stage can be divided into two parts: during the attack and after the attack. It would only be after this stage is over that one could determine which part a specific moment belonged to. But in this stage, keeping in mind the possibility of a second strike (which could involve the use of another nuclear weapon, or lethal means other than nuclear weapons, including chemical weapons such as sarin), the following responses would be attempted mainly by a local nuclear emergency response headquarters under the direction of the central government nuclear emergency headquarters.

① Collection and communication of information

② Decisions on emergency responses to carry out

③ Implementation of emergency responses

As a precondition for all three of these emergency activities, it would be essential to ensure that the command center of the local nuclear emergency response headquarters functioned properly. To do so, however, would not be easy. (Various scenario analyses and simulations conducted by the U.S. and other countries rarely assume the breakdown of the command center’s functions, which is too optimistic an attitude.)

Located in the center of Hiroshima City, the municipal and prefectural offices are highly likely to suffer catastrophic damage from a nuclear weapon attack targeted at the city center. In case such an attack occurs, it would be necessary to gather the government officials and staffers who survived the first attack and establish a provisional command center in a building that had been spared major destruction and was relatively less contaminated with radiation. Yet, it would still take substantial time to establish this new command center, and even if established at all, its functions would be extremely limited.

Furthermore, a nuclear weapon attack made by a state or other entity with sufficient economic and technological capabilities is generally expected to involve detonation of multiple nuclear weapons directed at many different targets either in a simultaneous or staggered manner. For instance, if nuclear weapon attacks are delivered against several cities, the central government headquarters in Tokyo would not be able to sufficiently commit to address the situation in Hiroshima City. And if the attack were targeted at Tokyo, among other cities, it would lead to the complete destruction of the Nagatacho and Kasumigaseki districts where government buildings are concentrated, making it impossible to promptly establish a central government nuclear emergency response headquarters. Even if a number of high-ranking government officials, including the prime minister, survived the attack and are able to quickly set up a central government headquarters, most of their activities would be expected to focus on disaster mitigation in Tokyo. In this scenario, Hiroshima City, no matter how devastated it might be, would have to cope on its own with the nuclear disaster, in cooperation with Hiroshima Prefecture and neighboring municipalities.

Another issue of concern is that the establishment of a top-heavy emergency response mechanism specified under the Civil Protection Law and Nuclear Disaster Law is expected to take a considerable amount of time. In contrast, a nuclear weapon attack would bring about devastation instantaneously, delivering the extent of its damage in a brief period of time. Any delay in initial action would result in disastrous consequences. Yet, whether the mechanism specified under the Civil Protection Law and Nuclear Disaster Law ensures effective responses to a nuclear weapon attack remains an open question. This is the main reason why voluntary measures need to be taken on a local basis before the central government nuclear emergency response headquarters can begin functioning in real earnest.

The following paragraphs discuss the difficulties associated with each of the above-mentioned three types of nuclear emergency responses.

① Collection and communication of information

Though it is the basis for all emergency responses, this step involves enormous difficulties. In light of the previously discussed radiological protection standards, access by disaster prevention officers to areas severely contaminated with residual radiation would be virtually impossible for at least several days after the explosion. The means collecting information concerning contaminated areas would be limited to observation from above by airplane, helicopter, satellite, etc., and measurement using a limited number of instruments owned by local research or educational institutions or brought in from outside. Nuclear power stations and other relevant facilities are equipped with their own emergency information collection and analysis systems, but Hiroshima City has no such systems. Moreover, telecommunications networks would be extensively devastated by the blast, thermal radiation, nuclear radiation, fires, electromagnetic pulse, etc. In the same way, the electrical system that powers these telecommunications networks would suffer enormous damage, making it difficult to obtain more than sketchy, general information concerning the statuses of damage and contamination.

The shutdown of telecommunications networks would also hinder the communication of information to disaster prevention officers and residents. Direct communication of information using loudspeakers from vehicles or helicopters would be obstructed and made impracticable by heaps of rubble and strong residual radiation.

② Decisions on emergency responses to carry out

What constitutes the core of emergency responses is instructing residents whether to evacuate or seek shelter, and providing residents who have evacuated or found shelter with relief, such as water, food, and medical care. Other responses could include preventing the spread of damage, securing utility lifelines, and restoring devastated areas. While all these measures would be challenging, the most difficult task would be the issuing of appropriate instruction to citizens at each location on whether to seek shelter (indoors or inside concrete buildings) or to evacuate. Some argue that this would be the most important factor affecting the number of casualties [52].

Dividing the city and its surrounding areas into three zones will make it easier to carry out emergency responses in a systematic manner.

4. Second-stage responses to a nuclear weapon attack: After the beginning of a nuclear attack

i) Severely affected ground zero zone

ii) Intermediate zone experiencing a certain extent of damage, fires and believed to have a high risk of radioactive contamination

iii) Surrounding zone located more than several kilometers away from ground zero, suffering minor damage

These zones would not form concentric circles around ground zero but would be of complex shape due to the wind direction and other weather conditions. The size of each zone would vary depending on the explosive power of the nuclear weapon used. This zoning process, which would be the basic step in formulating emergency response policies, must be carried out allowing for substantial margin of error associated with the uncertainty of available information and the variability of weather conditions. Furthermore, these zones must be updated from time to time so as to reduce the range of uncertainty.

In the ground zero zone, most buildings would collapse or suffer major damage with fires breaking out across an extensive area. At the time of the explosion, lethal doses of radiation are expected to fall. All these developments would cause the deaths of a great majority of the residents. The electromagnetic pulse would devastate the telecommunications system in the zone. With no information available, surviving residents would be expected to evacuate ground zero as soon as possible. But destruction of transportation networks would require them to get out of the affected area on foot, leaving them at a higher risk of massive exposure during evacuation.

Meanwhile, since residual radiation decays with time, temporary shelter (for a brief period of time from a few hours to ten-plus hours) could be an option in exceptional cases such as when an underground town, basement, etc. are left virtually intact or robust concrete houses remain almost undamaged in nearby areas. It should be noted, however, that this means of temporary shelter could also involve tremendous risks.

For one thing, it would be extremely difficult to reach the entrance to an underground town in the vicinity of ground zero, as the area would be subject to significant devastation and chaos immediately after the attack. Moving from one place to another would take much longer than expected, subjecting individuals to massive radiation exposure. Even if individuals manage to make it to the entrance to the underground town, the entrance and its surroundings are expected to be obstructed by concrete rubble, blocking access to the underground town. And even if the entrance were open, the stairs would probably be destroyed. Individuals might be able to crawl down the slope and make it to the underground town only to find it crowded with a vast number of injured persons and in pitch darkness. Under these circumstances, water, food and first-aid supplies would be scarce. Relief from outside would be out of the question. Radiation would continue streaming in relentlessly through the entrance. Crowding a narrow space with a large number of people who have been exposed to radiation would in itself pose a high risk of radiation exposure. The worst-case scenario is that a cloud of radioactive fallout remains hanging over a huge number of evacuees rushing to the few entrances that have been spared destruction and waiting in lines to enter the underground town. Another possibility is that widespread, protracted fires would cause a rise in temperature and lack of oxygen in the underground town as well. Being an enclosed space, an underground town would be vulnerable to fires.

Artificial chemical materials would produce toxic gases when burned, too. Therefore, it would not be a viable option for survivors in this zone to seek shelter above ground.

In the intermediate zone just outside ground zero, many buildings would be spared collapse or major damage and many people would be spared death from the explosion. However, this zone will contain areas subject to massive radiation exposure, such as downwind areas to which a cloud of radioactive fallout is expected to drift or hot spots on which high doses of radiation would land in concentrated form as black rain depending on weather conditions. Therefore, a decision regarding whether to seek shelter (for a short time) or evacuate might depend on weather conditions such as the wind direction and on the extent of destruction and paralysis of the transportation networks. It is in this intermediate zone where it would be most difficult to make the right decision. Taking into consideration the transport capacity of the remaining means of transport and placing top priority on saving lives, one would have to make the more appropriate choice. An attempt to evacuate a large number of residents all at once could exacerbate traffic congestion, possibly stranding survivors under a cloud of radioactive fallout.

In the surrounding zone quite distant from ground zero, physical damage to buildings would be very limited. Even if individuals stay there for a long time (from a few days to ten-plus days), chances are extremely slim that they would develop acute radiation sickness. One of the conditions for being defined as a surrounding zone is to keep accumulated exposure dosage well below 100 mSv. In this zone, disaster prevention officers can conduct relief activities for many hours on end. Residents would not have to evacuate the zone so quickly. Still, while evacuation would not urgently be needed, residents who are in a situation where evacuation is a relatively easy option should not hesitate to evacuate the zone, and administrative agencies should take measures to support their decision. Needless to say, in terms of priority, more emphasis should be placed on assisting evacuees from the ground zero and intermediate zones than those from the surrounding zone. Residents who find early evacuation difficult would be required to take the kind of thorough radioactivity-protection measures that were taken by residents in Europe, particularly Germany, at the time of the Chernobyl disaster[37].

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37 While protective measures varied depending on countries and provinces, the essential measures comprised the following four steps: 1) avoid drinking water and foods suspected of having been contaminated with radiation and, for the time being, consume only foods that have been processed before radiation contamination. Particular attention should be paid to milk and fresh vegetables that would immediately be affected by radiation. Attention must be paid to other foodstuffs that would also be subject to the effects of radiation before long; 2) refrain from going out unless it is urgent and unavoidable. When it is necessary to go out, make sure to wear a mask, hat, overcoat, etc. For the mask, it would be much better to wear a simple dustproof mask. On returning home, make sure not to bring these things inside the house. Take off your shoes at the entrance to the house. Pregnant women and children are particularly encouraged to avoid going outside. Also avoid going out in the rain. After returning home, take a shower (unless the water is contaminated) and change your clothes; 3) at home, keep windows closed and seal them off with adhesive tape, etc. any openings through which air could come in from outside. Spend as much time as possible in the center of the house (away from walls or the roof); and 4) refrain from draining or disposing of water or articles suspected of having been contaminated with radiation. It should also be noted that there would be instances in which individuals should refer to information from various sources, instead of from administrative agencies alone, and make calm and balanced judgment on their own. Works on citizens' experiences during the Chernobyl accident include "Under the Chernobyl Cloud" by Tashiro Jannes Kazuomi (1987: Technology and Humans).

Given these discussions, it should be concluded that seeking shelter indoors is not necessarily superior to evacuation. Seeking shelter would no doubt be a much easier option than evacuation and there is no denying that evacuating hundreds of thousands of people would be an extremely challenging task. All the same, in cases where decision-making is difficult, one must place priority on saving lives and make decisions regardless of expected implementation difficulties.

In any case, in situations where real-time information gathering is extremely difficult, it would be practically impossible to make appropriate decisions on whether to shelter or evacuate survivors.

Although the possibility of a second strike was not mentioned in the above discussions on evacuation and shelter, individuals are required to note that such a possibility is not unlikely when they are actually evacuating or seeking shelter. For example, a second strike might be directed at the procession of survivors fleeing from fires and heading for suburban areas on foot. Delivering a sarin gas attack or throwing fire bombs at a crowd of survivors taking shelter in an underground town would also have an immensely alarming effect. Needless to say, the risk of such multiple attacks delivered one after another should be taken into account in emergency response operations. Simply issuing warnings regarding such possibilities could have a substantial effect, possibly putting the brakes on hasty and misdirected evacuation and relief operations.

③ Implementation of emergency responses

It would be a major challenge to carry out emergency responses in an organized, systematic manner. For one, it would be difficult to deploy a sufficient number of qualified disaster prevention officers because there are very few people with expertise and experience concerning radiation/radioactivity. Another limiting factor is that the number of protective suits, protective masks and dosimeters available for these officers would determine the number of officers that could be mobilized. Moreover, if responders will be subjected to large doses of radiation, dispatching on a volunteer basis would be desirable. But the number of officers who would volunteer might be quite limited. It might be possible to secure more people if volunteers were recruited from employees at civilian nuclear facilities throughout the country. Still, it remains an open question whether it would be justified to expose such civilian personnel to potentially dangerous operations that could require them to risk their lives only because they have relevant expertise and experience. Besides, recruiting from civilian facilities would not necessarily guarantee securing a sufficient number of crews.

Even if a certain number of disaster prevention officers were secured, it would be almost impossible for them to access the ground zero zone and give instructions and guidance to survivors for at least several days after the attack. Using robots or other unmanned means could become possible in the future, but for now, such means are still far from practical. Meanwhile, in the intermediate zone, it would be possible to engage in disaster prevention with officers wearing protective suits, protective masks and dosimeters. This would include various activities, such as guiding and assisting survivors during evacuation and shelter-seeking and conducting other mitigation operations (firefighting, etc.) for very short periods of time until an alarm on the radiation detector goes off. Yet, given the extremely limited number of disaster prevention officers that could be mobilized, it would be quite unlikely that these activities would produce any substantial effects. Under these circumstances, then, in which information from the outside were entirely unavailable, residents in the ground zero and intermediate zones would have no choice but to evacuate or seek shelter on their own, using their own knowledge and own sense. It can easily be imagined that this kind of action on the part of residents would eventually result in general chaos. If combined with a second strike or other accidental events, in particular, it would be impossible to avert the emergence of a state of panic.

Furthermore, a large number of disaster prevention officers might carry out rescue operations for multiple hours, rescuing survivors at the expense of exposing themselves to massive doses of radiation. In addition, many residents may encounter the same situation when trying to help their families and loved ones. Inspired by natural human emotions, their behavior should not be viewed as particularly irrational. The radiological protection standards for emergency situations do not consider intimate personal relationships, nor do they place top priority on minimizing loss of life. Therefore, excessive adherence to these standards might be judged as not applicable in actual emergency situations.

And yet, disaster prevention officers have a professional duty to conduct the maximum possible emergency response operations within the limits of available manpower and equipment. Therefore, they would have to consider how to manage the dilemma they face; the rescue of survivors versus possible casualties among the emergency responders themselves. Being valuable human resources that could be deployed for other activities, some argue that disaster prevention officers would be better able to save more citizens by leading decontamination efforts and providing assistance in medical treatment in the surrounding zone than by engaging themselves in rescue operations near ground zero [54]. It would be difficult, however, to appropriately judge the best activity at any given time.

In any case, relief operations would begin in real earnest only after survivors had finally reached the surrounding zone, mainly on their own initiative, but also thanks also to the guidance and assistance of disaster prevention officers. The first step to take would be decontamination of survivors[38], which would help prevent additional exposure from radioactive materials attached to their bodies and clothing. Another possible step would be to give survivors a chelating agent that absorbs radioactive materials in the body and aids in their discharge.

After these steps, treatment would be provided to injured individuals, but this is the most difficult stage in nuclear emergency response. From the ground zero zone to the intermediate zone, most medical institutions would be destroyed or disabled, leaving many of their staff members, including doctors and nurses, dead or injured. Under these circumstances, medical institutions in the surrounding zone and other cities would have to play the central role in treating survivors.

Specifically, in addition to hospitals in the surrounding zone that have been spared

[38] Although survivors can decontaminate themselves by removing clothing contaminated with radioactive materials and washing radioactive materials off their bodies by taking a shower, a huge facility would be necessary to store the contaminated clothing that the survivors have taken off and the water they have used.

damage from the attack, a number of temporary patient accommodations (including open-air hospitals) must be built. Also, patients would have to be transported to hospitals in neighboring cities. Those suffering from severe acute radiation sickness or burn injuries, among other survivors, must be sent to special hospitals. All these hospitals and facilities, however, would still not be enough to provide the necessary care to the tens of thousands or more survivors.

This is why triage (prioritizing patients) should be conducted first to ensure the most effective utilization of limited medical resources (medical staffs, medicines, etc.). Triage would be conducted so as to concentrate care on patients who are severely injured but have a greater chance of being helped, while giving only first-aid treatment to those unlikely to be helped by any means and those not suffering from any life-threatening injuries.

Relief activities other than medical care would also face various challenges. This is because, compared to other disasters, the number of injured would be much larger and the severity of injuries generally greater in nuclear disasters. Another reason is that radioactive contamination would be extremely widespread. It would be difficult to secure uncontaminated water and food. Daily necessities taken out of contaminated areas would be no longer usable. Those transporting goods into the affected areas must be prepared for the risk of radiation exposure. It should not be expected that volunteers will easily join in relief activities.

The ground zero zone would be restricted for a substantial period of time, preventing implementation of search and rescue operations. It would also be impossible to dispose of a vast number of dead bodies because it would involve exposure to significant amounts of radiation. In the meantime, decomposition would set in, making it difficult to identify many of the bodies, especially those of the victims burned to death on the spot by thermal radiation. Radioactive contamination would also hinder reconstruction of the affected areas as well. Lowering radiation levels below the dose limit of public exposure would be essential for rebuilding an affected city, and would involve a long period of decontamination operations and an enormous amount of money.

In a surface burst, in particular, far higher quantities of radiation would result than a comparable air burst, possibly leaving many areas semi-permanently inhabitable.

While it is difficult even to estimate the amount of damage, some estimates do suggest that the surface burst of a 10-kiloton weapon would result in initial losses exceeding one trillion dollars [55, 56].

5. Limitations of responses

As discussed so far, if a nuclear attack were to occur, it would be entirely impossible to avoid extensive damage. Even the best possible emergency responses implemented by administrative agencies would do nothing more than slightly mitigate the catastrophe. Nuclear weapons are too destructive and the radioactive contamination caused by them too severe to enable adequate response operations.

In concluding this chapter, it should be emphasized that the psychological and physical injuries inflicted on survivors of a nuclear weapon attack would never be healed, no matter how many years of effort and how much money was invested. It would be utterly impossible, among other things, to cure the emotional wounds of those caught in the horrendous devastation in the ground zero zone, barely able to escape. Furthermore, survivors would never be free from the fear of developing the aftereffects of radiation exposure. Another source of concern is that not much is known even today about the influences of nuclear disasters on future generations, in spite of the tragedies of Hiroshima and Nagasaki and all the other nuclear disasters experienced by humankind. Lack of support for survivors, combined with public discrimination and prejudice against them, would likely hinder their psychological and physical recovery and would cause them various difficulties in their professional and social lives.

Chapter 6: Conclusion

This Committee has been charged with the mission of (1) creating damage scenarios that would result from a nuclear weapons attack and (2) putting forward measures that Hiroshima City should adopt in view of the scenarios drawn up.

The Committee's individual findings have been detailed in Chapters 4 and 5. In this concluding chapter, the Committee wishes to present our answer to the question, "Is Japan capable of dealing with the consequences of a nuclear weapons attack, and if so, what measures do we need to adopt?"

In the scenarios described in Chapter 4, we demonstrated that due to the protection offered by sturdy buildings, casualties – especially fatalities – may well be considerably fewer than those of 62 years ago but that there was virtually nothing that an individual could do to prevent the spread of damage.

In Chapter 5, we discussed the creation of a system to deal with the contingencies. There would be a need for a system on a national level but in view of the vast scale of the disaster and of all aspects of post-attack activities being hampered by the adverse effects of radiation, we concluded that no matter how government bodies tried to deal with the situation, the effect would be merely to reduce the casualties on a minute scale.

Certainly, if prior warning could be given to make people take shelter indoors, human casualties might be greatly reduced. Or, perhaps in areas far removed from ground zero, evacuation measures might be successful and casualties might thereby be reduced to some degree. Nevertheless, even if the casualties are reduced in this way, it is difficult to describe or quantify. What is more, there are no effective means of dealing with the late disorders that result from radiation and the long-term damage resulting from the breakdown in families and communities.

Therefore, it is quite impossible to claim that civilians can be protected from a nuclear weapons attack on the grounds of possible reduction in short-term human casualties. There is no other measure to protect civilians than to bar the use of nuclear weapons. This fact has been repeatedly shown in the results of field research conducted on the damage suffered by Hiroshima and Nagasaki[39] and in the World Health Organization (WHO)'s report[40]. There are those who advocate the adoption of nuclear arms as a means of preventing nuclear weapons use. However, we demonstrated in Chapter 2 that the possibility of nuclear weapons use cannot be eliminated even under a framework of nuclear deterrence. In fact, such an approach would instead accelerate nuclear proliferation, pushing the whole world to greater instability

Consequently, to the initial question posed, this Committee can present no answer other than the following: It is not possible to protect civilians from a nuclear weapons attack. To protect civilians, there is no measure other than to prevent a nuclear weapons attack from occurring, whether it be deliberate or accidental. To prevent the use of nuclear

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[39] "As far as the protection of the population in general is concerned, it would be honest to say that except for special cases, there are almost no measures that can be adopted. Therefore, there is no other foolproof means of protection than to prevent the explosion of an atomic bomb." [57]

[40] "It is obvious that the health services in the world could not alleviate the situation (resulting from the use of nuclear weapons) in any significant way" [58]

weapons, there is no way other than to abolish nuclear weapons themselves.

In this regard, the international community shares the following roadmap in its vision of achieving a nuclear-weapons free world. In summary, the way forward is to reinforce the NPT framework from both the nuclear disarmament and non-proliferation standpoints while promoting talks for the total abolition of nuclear weapons as pledged in Article VI[41] of the NPT Treaty by all signatories including Nuclear weapon States. The ultimate goal of the talks is to reach a treaty banning nuclear weapons (NWC)[42] as has been achieved for biological and chemical weapons. Various forums for NWC talks are envisaged: the Geneva Conference on Disarmament (CD) needless to say, as well as methods such as the Ottawa Process which delivered success in the Mine Ban Treaty, whereby like-minded states and NGOs work together.

Although progress appears irrefutably too slow, the international community is taking steps forward by establishing bridgeheads a little at a time. In July 1996, the International Court of Justice gave an advisory opinion[43] that the obligation set out in Article VI of the NPT is a twofold obligation on nuclear disarmament, not only the pursuit of negotiations in good faith but also of concluding negotiations. Propelled by this advice, the New Agenda Coalition[44] was formed in 1998. Under its strong leadership, the 2000 NPT Review Conference unanimously adopted the Final Document, in which the Nuclear Weapon States renewed their “unequivocal undertaking to accomplish the total elimination of their nuclear arsenals leading to nuclear disarmament.”

The 2005 NPT Review Conference failed to move this further forward but a noteworthy proposal has appeared in the international community as the next step to this “unequivocal undertaking.”

The Weapons of Mass Destruction Commission established under the sponsorship of the Swedish Government (Chairman: Hans Blix; often referred to as the Blix Commission) submitted a report [59] in June 2006 after a detailed inquiry, making 30 recommendations on nuclear weapons. In the last of these recommendations, the Commission requested that “All states possessing nuclear weapons should commence

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41 Treaty on the Non-Proliferation of Nuclear Weapons, Article VI: Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.

42 A Model Nuclear Weapons Convention was submitted to the UN in December 1997 and circulated by the UN as Doc A/C.1/52/7. An updated version of this, a Model Nuclear Weapons Convention (NWC) was submitted by Costa Rica in May 2007 as working papers (NPT/CONF.2010/PC. I/WP.17 to the 2010 NPT Review Conference.

43 ICJ’s advisory opinion “F, Unanimously, There exists an obligation to pursue in good faith and bring to a conclusion negotiations leading to nuclear disarmament in all its aspects under strict and effective international control.”

44 Group of states that pledged to spearhead the abolition of nuclear weapons – currently comprising the seven countries of Ireland, Sweden, Mexico, Brazil, New Zealand, Egypt and South Africa.

planning for security without nuclear weapons" since they had promised the total elimination of their nuclear arsenals.[45]

Former United Nations Secretary General Kofi Annan delivered a comprehensive speech on nuclear weapons [60] at the end of November 2006 before retiring from office. In this speech, he emphasized the need for progress on both nuclear disarmament and non-proliferation and urged all nuclear weapon States to develop concrete plans with specific timetables so as to implement their "unequivocal undertaking".[46]

On January 4, 2007, as if to respond to these calls for action, four former cross-party high government officials including Henry Kissinger, who had been actually responsible for the US nuclear weapons policies in his time, wrote an article in a US newspaper entitled "A World Free of Nuclear Weapons" [61]. In this article, they stated that the leadership of Acknowledged States, especially the United States, was important. They wrote:

"First and foremost is intensive work with leaders of the countries in possession of nuclear weapons to turn the goal of a world without nuclear weapons into a joint enterprise. Such a joint enterprise, by involving changes in the disposition of the states possessing nuclear weapons, would lend additional weight to efforts already under way to avoid the emergence of a nuclear-armed North Korea and Iran."

They made proposals on specific action that could form part of the joint enterprise, including the de-alerting of nuclear weapons use, the abolition of tactical nuclear weapons, the promotion of the ratification of the Comprehensive Test Ban Treaty (CTBT), and the ban on the production of nuclear materials for weapons use (cut-off). However, these individual suggestions were all things that had been proposed before. The thrust of their appeal was in their call for "bold vision and actions" that would turn the work into a joint enterprise.

As to the specific agenda for actions needed to achieve "a world free of nuclear weapons" as has been carefully considered on the international level, this Committee would draw the line at recommending the three proposals mentioned above – the Blix Report, the speech by Kofi Annan and the proposals by the high-ranking US government officials. As is often said, technical methodology already exists. What is needed is the political will. (For Japanese translations of the relevant passages of the above three proposals, see Appendix E.)

To strengthen the political will of all governments to achieve nuclear disarmament, especially the political will of the Nuclear Weapon States, the vital ingredient is rising pressure from civil society. The results of the deliberations of this Committee indicate the seriousness, especially in cities, of casualties resulting from a nuclear weapons attack. Therefore, all cities of the world must be a driving force in rousing public opinion towards nuclear disarmament. This is a necessary and also effective course of

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45 Recommendation 30 "From regulating nuclear weapons to outlawing them: All states possessing nuclear weapons should commence planning for security without nuclear weapons. They should start preparing for the outlawing of nuclear weapons…"

46 In it, he proposes, "I call on all the States with nuclear weapons to develop concrete plans – with specific timetables – for implementing their disarmament commitments.

action. Aggressive action is expected from the Mayors for Peace[47] on the world level and from the National Council of Japan Nuclear Free Local Authorities[48] on the domestic level.

The role that Hiroshima City has to play towards achieving nuclear disarmament is enormous. We wish to end this Report by expressing our expectation that Hiroshima City will step up its actions yet another level.

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47 Established in 1982 at the suggestion of the mayors of Hiroshima and Nagasaki. (As of November 1, 2007, the membership extends to 1,828 cities of 122 countries and regions.) It is promoting the 2020 Vision Campaign, which sets out to achieve total abolition of nuclear weapons by 2020, which will be the 75th anniversary of the atomic bombings in Hiroshima and Nagasaki. From July 2006, the 2020 Vision Campaign entered Phase II, Good Faith Challenge, and the Cities Are Not Targets (CANT) project was launched. The 2020 Vision Campaign has been given resolutions of agreement by the National Council of Japan Nuclear Free Local Authorities, the Japan Association of City Mayors, The United States Conference of Mayors and the United Cities and Local Governments (UCLG) which is a world association of local governments that represents the majority of the global population (a total of more than 2,500 local governments and regional organizations of 127 countries/regions out of the 192 UN member states) <http://www.mayorsforpeace.org/english/>

48 Established in 1984 with the following aims: "It is an important mission given to local authorities to protect the lives and livelihoods of every single citizen from the dangers of human extinction through nuclear warfare and to contribute to the achievement of permanent world peace for the benefit of present and future populations. The local authorities that have declared themselves nuclear free would join forces and urge local authorities throughout the world to realize the abolition of nuclear weapons and to create lasting peace, until such a day as when nuclear weapons disappear from the surface of the earth, and in addition would endeavor to spread the movement. 240 local authorities in Japan are members (as of October 1, 2007). It works towards achieving its founding aims through its general assemblies, national conferences and workshops as well as diverse peace projects. <http://www.nucfreejapan.com/>

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