Nuclear Bodies

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# Nuclear Bodies

## The Global Hibakusha

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For Dylan and Max

# Contents

## Part IV. Heirs

# Preface

Millions of people around the world have suffered harm from radiation since the nuclear attacks on Hiroshima and Nagasaki in 1945. Their bodies form part of the fabric of ecosystems where nuclear fallout deposited radioactive particles—whether from nuclear weapon testing, nuclear power plant accidents, or the production of materials used in both technologies. These exposures have led to deaths, illnesses, forced evacuations from homes and communities, continued habitation in radiologically contaminated landscapes, tainted food sources, and endless anxieties and emotional distress. The experiences of these "global hibakusha" have been largely invisible to us because they happened primarily in colonial, postcolonial, or remote parts of our world, or to people with little political recourse. (*Hibakusha* is a Japanese word denoting a survivor of the attacks on Hiroshima and Nagasaki.)

Based on its belief that nuclear weapons were likely to be used in warfare after 1945, the United States conducted large-scale studies to understand the medical consequences of exposure to radiation from the detonations of these weapons. The studies focused on the large bursts of external radiation (primarily gamma waves) that ravaged human bodies in Hiroshima and Nagasaki, but they ignored radioactive particles that cause harm when internalized inside of the body. The radioactive waves remain close to the hypocenter and last less than a minute, while the radioactive particles can travel far downwind and remain dangerous anywhere from a few hours to millions of years later, depending on the specific chemistry of the particle.

World War III never happened, but the detonation of more than two thousand nuclear weapons in “tests” did happen. During these tests, the external waves of radiation were contained to the test sites; however, mushroom clouds heavy with radioactive particles drifted downwind, where those particles could “fall out” and affect the health of living creatures. Long-lived fallout particles embedded into the ecosystem and will continue to pose threats to health: plutonium will remain dangerous for over two hundred thousand years, and uranium particles for more than one million years. Areas where particles fell out in large amounts near Chernobyl and Fukushima are still vexed by $^{137}Cs$ (cesium-137), a particle that remains dangerous for over three hundred years; easily transports through water, plants, and animals; and has shown up consistently in food produced in downwind zones decades later. Millions of people live in places where these disasters happened; whole communities have been devastated and many abandoned.

The invisibility of these global hibakusha is manufactured in both science and politics. Studies of the hibakusha in Hiroshima and Nagasaki built models of risk on external exposures and ignored the internal exposures that would become far more common. Since the global hibakusha’s exposures do not fit our health models, we are unable to see them as enduring risk from radiation. Politically, nuclear weapon states do not want to acknowledge that weapon effects like fallout—which are designed for use in warfare to sicken and kill—constitute actual warfare when inflicted on people during “tests.” This is not information that emerged slowly; awareness of the health impacts from fallout is what originally led nations to establish their test sites far from the elite populations in their societies. Some nuclear weapon states never tested in their own countries; others established test sites upwind of ethnic minority populations. Countries like the United States, the United Kingdom, and France tested large thermonuclear weapons on small Pacific islands and atolls that were either colonial or postcolonial trust territories. Awareness of the risks to communities downwind drove those siting choices; little care was given to the actual people living there.

Conversely, nuclear power plant accidents happen in developed nations to communities with some measure of political agency and access to information. The perceptions about radiation of these populations are more actively managed, in part because of their rights to compensation. For these people, the studies of the hibakusha from Hiroshima and Nagasaki are invoked to convey that levels of radiation in zones downwind from explosions, such as at Chernobyl or Fukushima, are too low to be of medical consequence. However, explosions from nuclear power plant accidents also raise clouds of radioactive particles into the air and deposit them downwind. Defenders of nuclear power dismiss downwinders' health concerns and describe people living in contaminated areas as suffering from an irrational fear of radiation, which they pathologize as "radiophobia." When a nuclear disaster happens upwind of your home and fallout clouds deposit radionuclides into your environment, anxiety is a rational response. Communities in need of information and assistance are instead routinely chastised for reacting to the toxic disaster thrust upon them.

The risks from radioactive particles and their behavior in ecosystems were well-known from the start. Senior Manhattan Project scientists had considered using radioactive particles as an offensive weapon against the Germans in World War II long before nuclear weapons were successfully manufactured; they discussed aerosolizing radionuclides so that enemy soldiers would internalize lethal amounts through inhalation. In 1946, after the first American postwar nuclear tests in the Marshall Islands, scientists made extensive studies of the behavior of fallout particles in the waters, soils, and biota of Bikini Atoll and strategized how to best weaponize these effects to both kill and psychologically terrorize an enemy population. Throughout the Cold War, military planners on all sides designed attacks that would weaponize fallout radiation to massacre enemy populations. All of this took place while simultaneously asserting that these same fallout clouds posed no health risk to people living underneath them downwind from test sites. They behaved as though the direct use of fallout radiation in warfare was strategic and calculated, while indirect exposures from testing, production, and accidents were "inconsequential" and "below health concerns." In fact, the effects of fallout do not change depending on the intentions of the party doing the irradiating.

The Cold War was, in part, a limited nuclear war conducted against these communities. We imagine that the nuclear war didn't happen because we had been envisioning the protagonists attacking each other, but the two thousand weapons detonated during the Cold War had profound impacts. The effects on global hibakusha communities—early mortality, disease, displacement, contamination of food sources and ecosystems—constitute a limited nuclear war. The fact that the locations where this happened are on the periphery of our political consciousness is why we are unaware of what happened, and also why they were chosen in the first place.

As the Cold War nuclear arsenals continue to threaten human civilization today, the radiological risks to human beings also extend beyond the twentieth century. Many of the radionuclides produced for our weaponry and electrical generation have deposited all around the world and will continue to migrate through the ecosystem long past our own mortality. We are on the temporal front lines of countless generations of human beings for whom these particles, and millions of tons of radioactive waste, have been stitched into our planet. Much of the waste is classified as high-level and will remain dangerous to living beings for more than one hundred thousand years. It is currently located on every continent (except Antarctica), although primarily in the global north; we plan to bury the most dangerous of it—the spent nuclear fuel—half a kilometer underground in dozens of sites in an attempt to contain the risks. Deep geological storage sites are already under construction in many countries, including Finland and Sweden, and many more are under design. These will present a risk to thousands of generations of human and other beings. We wrestle with what instructions to leave beside the waste—instructions we imagine will help protect people in the future—oblivious to the fact that the presence of our waste in their world is itself the message.

Hundreds of thousands of metric tons of this high-level waste is here now. We cannot keep it out of the future; in a sense, it's already there. But we can do a better or worse job of management. Being responsible about our waste means centuries of funding the facilities necessary to contain it (whatever methods we settle on) and remediating the sites of our production, testing, and accidents. We must compel numerous administrations in multiple governments to fund these remediations and storage sites for centuries. We have already made the central mistake, manufacturing hundreds of thousands of tons of radioactive toxins that will remain harmful for millennia, and so we have to commit our societies to responsible stewardship. The most important thing we must do is to stop making more nuclear waste: we must abolish nuclear weapons and abandon nuclear power.

Our invention of nuclear power plants to produce plutonium and the subsequent invention of nuclear weapons seemed like a powerful path to effectively achieve some immediate outcomes. It turns out we were opening the door to a millennia-long journey, and none of our descendants can opt out: we've made the choice for them. Now we must be more mindful about what we have done and are to do. If we are unwilling to see where we have been, we will have little understanding of where we are going. Has our brutality called us to stewardship? Or has it just extended that brutality into multigenerational-temporal violence? This book seeks to shine light on elements of our recent history that we have buried away, how our actions have already inextricably shaped the future, and what choices remain to us.

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# Acknowledgments

This work is a synthetic look at the history and legacy of nuclear technologies. It grew out of a lifetime of contemplation on these issues, from childhood terror of nuclear weapons sparked by civil-defense drills in my elementary school in the 1960s, to living most of the last two decades in Hiroshima and being in Japan during the Fukushima nuclear disaster. A great deal of what has been integrated in this book stems out of my work on the Global Hibakusha Project with Mick Broderick, which began in 2010. Research for the project took us to numerous nuclear sites and into communities around the world, providing us countless nights to stew over what we had learned and absorbed, and the stories of the people we interviewed. Mick's intellect and passion is found throughout this book. Many of the oral histories cited in this book were collected by both of us during our years of fieldwork in radiation-affected communities.

While this is a work of global history, it is told from a Western perspective. Its source material is primarily in English, and even oral histories that have been gathered in the field were rendered into English by translators and interpreters. My own training is in both history of science and technology and American history, and so my grounding in the mechanics and particulars of American nuclear history and my proximity to its literature is evident throughout. There are a multitude of pathways into the history considered here, and I hope this work will be a strand in a braid of scholarship that tugs different points of origin and interpretation to provide a more complex story.

Over the dozen years of research and fieldwork that went into this book the number of people who have helped me in various ways is really not calculable. I am most grateful to my family, who have always been the ecosystem where I grow and thrive. My wife Carol helped every day to make this book and the research behind it succeed. Her wisdom and compassion are on every page. My sons and daughters, Kaya, Ocea, Gwynne, and Levi, are ever-present for me. I am lucky, in the way of this modern world, to find myself in the circle of multiple families: the Jacobs, Agrimson, Sala-Garcia, Horner, Haber, Wyatt, and Johnson families. Our cookbooks run deep. My kids by different parents, Yolanda and Dean, keep expanding our family joy.

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Studies at Hiroshima City University is a wonderful place to be centered. I am fortunate to be paid to do this work by the citizens of Hiroshima, who are my employers. At HPI, my close colleagues who have been there from my start—Narayanan Ganesan, Kazumi Mizumoto, Hitoshi Nagai, Makiko Takemoto, and Sung Chull Kim—welcomed me with open arms and hearts. I am forever indebted to our director, Ryo Oshiba; former directors, Gen Kikkawa, Motofumi Asai, and Haru Fukui; and colleagues, Akihiro Kawakami, Hyun Jin Sun, Xianfen Xu, Tetsuo Sato, Tadashi Okimura, Kyung Jin Ha, Chie Shijo, and Mihoko Kato. Also, every step of the path of this book has been made possible by the administrative staff of HPI, Yukiko Yoshihara, Miki Nomura, Yoshie Yamashite, and Yusuke Akishima, to whom I will be forever indebted. Thanks to my students: Dr. Ágota Duró, Dr. Atsuko Shigesawa, Pinar Temocin, Jerry O'Sullivan, and Ashley Souther. The staff of the Hiroshima Memorial Peace Museum and the Hiroshima Peace Culture Foundation provided ongoing assistance. Thanks also to others among my Hiroshima community, which includes Charlie Worthen, Masae Yuasa, Itsuki Kurashina, Ulrike Woehr, Luke Carson, Yoshi Furuzawa, Brenda and Evan Douple, Flo Smith, Carol Rinnert and Richard Parker, Tatsuya Nishida, Haruka Katarao, Tomoko Nishizaki, Nobuyuki Kakigi, Tomomitsu Miyazaki, Yumi Kanazaki, Ayako Yoshida, Miyuki Kahler, Junko Hatori, Eriko Noguchi, Andrei Mistretu and Eiri and Kaya-chan, Keiko Hiyama, Sane Mizushima at Café Igel, Erika Abiko and Mayu Seto at the Hachidori-sha Social Book Café, Naoko Koizumi, Yasuyoshi Komizu, Ron Kline, Mirei Tashiro and her daughters Leona and Maila, Joy and Paul Walsh, Prakash Lamichhane, Mitomo-san, and, of course, Boku and Yuri at Mac, for making coming to Hiroshima feel like going home from day one.

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## Abbreviations

| | |
|---|---|
| ABCC | Atomic Bomb Casualty Commission (US) |
| ACHRE | Advisory Committee on Human Radiation Experiments (US) |
| AEC | Atomic Energy Commission (US) |
| AFL | Applied Fisheries Laboratory (University of Washington) |
| AVEN | Association des Vétérans des Essais Nucléaires (FR) |
| BNTVA | British Nuclear Test Veterans Association (UK) |
| BREN | Bare Reactor Experiment, Nevada |
| CEP | *Centre d'Expérimentation du Pacifique* (France) |
| CLAB | Central Interim Storage Facility for Spent Nuclear Fuel (Sweden) |
| DGR | deep geological repository |
| DNA | Defense Nuclear Agency (US) |
| DOE | Department of Energy (US) |
| FBI | Federal Bureau of Investigation (US) |
| FRN | fallout radionuclides |
| GTW | global thermonuclear war |
| GZ | ground zero |
| HMNZS | Her Majesty's New Zealand Ship |
| IAEA | International Atomic Energy Agency (UN) |
| INWORKS | International Nuclear Workers Study |

| | |
|---|---|
| JCS | Joint Chiefs of Staff (US) |
| km | kilometer(s) |
| kt | kiloton(s) (of TNT equivalent) |
| LANL | Los Alamos National Laboratory (US) |
| LLNL | Lawrence Livermore National Laboratory (US) |
| LSS | Life Span Study (of the ABCC) |
| m | meter(s) |
| METI | Ministry of Economy, Trade and Industry (Japan) |
| MIRV | multiple independently targetable reentry vehicle |
| MOX | mixed oxide (nuclear fuel) |
| MRI | Mitsubishi Research Institute (Japan) |
| mt | megaton(s) (of TNT equivalent) |
| MT | metric ton(s) |
| MTHM | metric ton(s) of heavy metals |
| NAAV | National Association of Atomic Veterans (US) |
| NAS | National Academy of Sciences (US) |
| NATO | North Atlantic Treaty Organization |
| NGO | non-governmental organization |
| NPR | National Public Radio (US) |
| NRC | National Research Council (US) |
| NSC | National Security Council (US) |
| NTS | Nevada Test Site (US) |
| NWS | Nuclear Weapon State |
| ORNL | Oak Ridge National Laboratory (US) |
| PPG | Pacific Proving Ground (US) |
| PRA | probabilistic risk assessment |
| PRIS | Power Reactor Information System |
| PTSD | post-traumatic stress disorder |
| RAI | Rocketdyne/Atomics International |
| RECA | Radiation Exposure Compensation Act (US) |
| rem | Roentgen equivalent man |
| RERF | Radiation Effects Research Foundation (US/Japan) |
| RMI | Republic of the Marshall Islands |
| ROF | Royal Ordnance Factory (UK) |
| SAC | Strategic Air Command (US) |

| | |
|---|---|
| SDI | Strategic Defense Initiative (US) |
| SFP | spent fuel pool |
| SFR | Final Repository for Short-Lived Radioactive Waste (Sweden) |
| SKB | Swedish Nuclear Fuel and Waste Management Company |
| SNTS | Semipalatinsk Nuclear Test Site (USSR) |
| sRAW | solid radioactive waste |
| TEPCO | Tokyo Electric Power Company (Japan) |
| TNT | trinitrotoluene |
| UK | United Kingdom |
| UN | United Nations |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNSCEAR | United Nations Scientific Committee on the Effects of Atomic Radiation |
| US | United States |
| USPHS | United States Public Health Service |
| USS | United States Ship |
| USSR | Union of Soviet Socialist Republics |
| VA | Veterans Administration (US) |
| WIPP | Waste Isolation Pilot Project (US) |
| WHO | World Health Organization |

## Numbers, Chemical Isotopes, and Scientific Symbols

| | |
|---|---|
| 3/11 | 11 March 2011, the date of the earthquake and tsunami that triggered the Fukushima nuclear disaster |
| $^{14}C$ | carbon 14 |
| $^{90}Sr$ | strontium 90 |
| $^{131}I$ | iodine 131 |
| $^{137}Cs$ | cesium 137 |
| $^{230}Th$ | thorium 230 |
| $^{235}U$ | uranium 135 |
| $^{239}Pu$ | plutonium 239 |

| | |
|---|---|
| GBq | gigabecquerel |
| Gy | gray(s), unit of absorbed radiation dose |
| mSv | millisievert |
| mSv/year | millisieverts per year |

Nuclear Bodies

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# Introduction: Irradiated and Invisible

## Bravo

On 1 March 1954, the United States successfully tested its largest nuclear weapon on Bikini Atoll in the Marshall Islands: the first deliverable hydrogen bomb. The Bravo test sparked a revolution in US military capacity and strategy; it was a stunning technological achievement.[1] Since demonstrating two years earlier that a thermonuclear weapon was possible, US weapon labs in Los Alamos in New Mexico and Lawrence Livermore in California had been working to design an H-bomb small enough to be delivered to enemy territory by an airplane. The Bravo test succeeded beyond their wildest expectations and yielded an explosion twice as large as weapon designers had anticipated and a thousand times larger than the weapons used in the nuclear attacks on Japan.

The chief historian of the United States Atomic Energy Commission, Richard Hewlett, and his cowriter, Jack Holl, describe that "from the moment of firing *Bravo* gave every sign of being a spectacular success." The Bravo test was part of a series of six thermonuclear weapon tests in the Marshall Islands in March–April 1954, called the Castle series. Hewlett and Holl write that upon the completion of the series, "the future looked entirely different. It seemed that the American scientists had suddenly found the key to new realms of nuclear weapons. With a few notable exceptions, every new design principle incorporated in the *Castle* series seemed to work, often beyond the hopes of the most optimistic designers. . . . The

Atomic Energy Commission, the United States, and the world truly faced a new reality in the technology of war."[2]

Bravo and the other thermonuclear weapons tested in the Marshall Islands in spring of 1954 were imagined to have two profound impacts on the Cold War. The first was the scale of destruction that the weapons could inflict on the Soviet Union: "the hydrogen bomb was so enormous in its destructive power that it defied human description."[3] However, as US military commanders pointed out after the test, beyond the immense explosive power of these weapons was the scale of their radiological fallout. "It is now known that fallout from the larger Castle shots blanketed areas of more than 5,000 square miles with radioactive material that would have been lethal to unprotected personnel. This one result gives a new insight into a method for using high-yield weapons in both strategic and tactical situations."[4] Almost immediately the military began to draw up plans to quickly take advantage of these powerful weapons and their deadly fallout clouds. "In May 1954, Eisenhower was briefed on a paper by the JCS's Advance Study Group which proposed that the U.S. consider 'deliberately precipitating war with the USSR in the near future,' before Soviet thermonuclear capability became a 'real menace.' "[5] Eisenhower rejected such proposals; however, US military strategists immediately integrated the effects of these new weapons into nuclear war–fighting plans.

Eisenhower envisioned that the second impact yielded the true value of the new weapons: their deterrent capacity. The president's Cold War national security policy was formalized in 1953 in the document NSC 162/2. "When both the USSR and United States reach a stage of atomic plenty and ample means of delivery, each will have the probable capacity to inflict critical damage on the other, but it is unlikely to prevent major atomic retaliations. This could create a stalemate, with both sides reluctant to initiate general warfare."[6] Eisenhower believed that the weapons developed and tested during the Castle series would substantiate the threat of "massive retaliation" and effectively deter nuclear war. This is the envisioned logic of a robust and flexible nuclear arsenal during the Cold War: weapons that can almost instantaneously inflict apocalyptic damage deterring war, maintaining peace.

In describing the five-thousand-square-mile radioactive cloud that stretched downwind from the Bravo test, the top-secret 1954 film report

Radiation survey team, 1st Lt. W. J. Larson (USAF) and Ensign R. P. Keiser (USNR), measuring external radiation on unnamed residents of Utirik soon after arrival on 3 March 1954. Thomas Kunkle and Byron Ristvet, *Castle Bravo: Fifty Years of Legend and Lore: A Guide to Off-Site Radiation Exposures* (Kirtland, NM: Defense Threat Reduction Agency, 2013): 123.

of the Castle series mentions that it caused "significant fallout" to occur on Rongelap, Ailinginae, and Utirik Atolls, where "natives" were then evacuated on the "second morning after the shot."[7] Commander George Albin of the USS *Philip,* which evacuated those living on Rongelap and Ailinginae Atolls, later reported to Major General Clarkson, the head of Joint Task Force 7, which conducted the test, that "the Marshallese were excellent passengers, most cooperative, never demanding and exemplary in their conduct. It was a distinct pleasure for the crew of the PHILIP to have been afforded the opportunity to assist these quiet people in the evacuation."[8]

In total, 253 people were evacuated from Rongelap, Ailinginae, and Utirik Atolls.[9] These exposed Marshallese were examined by three radiobiologists assigned to Project 4.1, which was tasked with studying the

Utirik residents awaiting evacuation to USS *Renshaw,* 3 March 1954. Thomas Kunkle and Byron Ristvet, *Castle Bravo: Fifty Years of Legend and Lore: A Guide to Off-Site Radiation Exposures* (Kirtland, NM: Defense Threat Reduction Agency, 2013): 124.

health effects of those exposed to radioactive fallout during the test series. The radiobiologists' initial reports described that "Within hours of exposure to radiation, approximately two-thirds of the Rongelap people felt nauseated and one-tenth of the group had vomiting and diarrhea." These symptoms, which began before the evacuation and were suffered in lesser degree by those on the farther atolls, were followed twelve days later by "lesions of the skin and epilation of the head."[10] Later calculations estimated the average exposure of those from Rongelap (approximately 152 km away from Bikini) was equal to that of people who were 2.4 km from ground zero during the nuclear attack on Hiroshima.[11]

The Project 4.1 researchers continued to study the fallout-exposed Marshallese for decades. Subsequent research by the team, and researchers at the US National Cancer Institute, approximated that 170 additional cancers (beyond what was statistically expected) were produced among the Marshallese because of radiological fallout, predominantly thyroid cancers.[12] The Bravo fallout also contaminated numerous fishing vessels, among them the Japanese tuna boat the *Daigo Fukuryu Maru,* which was over 100 km downwind from Bikini Atoll. When the boat arrived back in Japan two weeks later, the entire crew was hospitalized with radiation sickness.[13] One crew member, Aikichi Kuboyama, died six months later of medical complications from his exposure.[14] The contaminated atolls were considered uninhabitable. Small portions were remediated by the US government during the subsequent years, and some of the displaced Marshallese were returned in 1957. The returnees began to suffer additional illnesses from ongoing exposures on the contaminated atolls and from eating local fish and plants. The Bravo test proved so disruptive and traumatic for the whole of Marshallese society that 1 March is currently a national holiday in the Republic of the Marshall Islands, observed as "Remembrance Day."[15] Thermonuclear weapons can generate five-thousand-square-mile lethal fallout clouds: when that radioactive fallout engulfs inhabited communities, it is no longer a "test." Bravo was experienced by those it irradiated as terror and harm.

## The Global Hibakusha

During the Cold War there were more than two thousand nuclear weapon tests. On average there were over forty-five tests per year between 1946 and 1991; statistically, a nuclear weapon exploded every other day during 1962, the year with the most tests.[16] Bravo was the detonation of one weapon on one day. We think of the Cold War as a period of time in which nuclear weapons were not used, but in reality, they were exploding continually. The tests began less than a year after the nuclear attacks on Hiroshima and Nagasaki and have been carried out on every continent except for South America and Antarctica. While never used directly against human beings since Nagasaki, these tests have profoundly affected communities around the world. Weapons have been tested by the United States in several Pacific nations and trust territories, and in Nevada—the location that has seen the most nuclear tests of any single place: 928. The Soviet

Union began testing in East Kazakhstan, then in the European Arctic, as well as in numerous other locations. The British tested in Australia, in Kiribati, and also in Nevada. The French tested in Algeria and then in French Polynesia. The Chinese tested in Lop Nor in Northwest China. India, Pakistan, and North Korea all tested underground and within their national borders. Israel has nuclear weapons but has not tested them.[17]

About one-quarter of the tests were in the atmosphere, facilitating the global distribution of radioactive fallout. Thermonuclear weapon testing created mushroom clouds that carried particles high above the troposphere and into the stratosphere, where they circled the Earth before falling back to the surface, sometimes years later. Subsequently, fallout radiation can be found everywhere around the planet. Its presence has provided scientists tracers with which to observe the fluid dynamics in global systems like the atmosphere and oceans. Their global ubiquity means we can determine whether goods were manufactured before or after 1945 because of the traces of anthropogenic (human-generated) radiation present in anything produced since the advent of nuclear testing. In the soil 3 km from ground zero in Nagasaki, a 2011 study found more radioactive particles deposited by global nuclear weapon testing than from the direct use of a plutonium weapon there in 1945.[18]

When detonated, nuclear weapons exert blast, heat, and radiation. Nuclear weapon states have been largely effective at keeping blast and heat effects contained to the test sites. Radiation can be encountered both as a wave and as a particle. When a nuclear weapon detonates, a burst of gamma and neutron waves spread outward from the reaction. In Hiroshima and Nagasaki these rays were harmful to a range of roughly 3 km from the hypocenter. With thermonuclear weapons, that diameter is larger. These radioactive rays can be understood similarly to X-rays: they are present and then they are gone. The burst and the danger last less than a minute, yet during that minute they can penetrate through most material, including human bodies. A person sufficiently far from the explosion will be unaffected by this burst. As seen at Bravo, there are also radioactive particles that are taken up into the mushroom clouds, travel downwind, and then "fall out" to deposit on the planet's surface, often hundreds or thousands of kilometers downwind.[19] These particles, classified as either alpha-emitting or beta particles (depending on their chemistry), can give off dangerous levels of radioactive waves when concentrated in large amounts, but they are particularly dangerous when they are taken inside the body through inhalation, swallowing, or cuts in the skin. In such cases, single particles can spark deadly diseases. Radioactive particles are not all the same; they are different chemical elements and isotopes of those chemical elements. These differences determine how radioactive a particle is and how long it remains radioactive. Some particles are dangerous for a few hours or days, others remain dangerous for hundreds of years, and some are dangerous for more than a million years. Depending on what and how many radionuclides you internalize into your body, you face differing degrees of risk for developing sickness or experiencing early mortality. When radionuclides deposit far downwind from nuclear test sites, they continue to present health risks to people, sometimes for longer periods of time than human life spans, thus endangering future generations.

While nuclear test sites were imagined to be located away from human habitation, fallout radiation traveled far outside of test site boundaries, affecting millions of people living downwind. Risks from radioactive fallout were well understood before the very first detonation, the Trinity test conducted on 16 July 1945 in New Mexico (three weeks before the attack on Hiroshima). Manhattan Project personnel were stationed in numerous locations to track the fallout and evacuate civilians in high radiation areas if necessary.[20] Fallout from the Trinity test was later found almost 2,000 km away in a field on the Illinois-Indiana border.[21] A 2018 internal report at Los Alamos National Laboratory details, "When Trinity's radioactive debris contaminated the grain fields of the Midwest, the response was to move testing to the Marshall Islands, where the seemingly empty ocean that [*sic*] would swallow any radioactive fallout. This scheme worked until Bravo demonstrated that the world was not big enough to hide the radioactive fallout from thermonuclear detonations."[22] Almost every atmospheric nuclear test has yielded radioactive fallout outside the boundaries of the military compounds in which they were conducted. Thermonuclear tests have often created "5,000 square mile" zones with lethal levels of fallout. Or larger. Today, substantial amounts of the fallout from Cold War nuclear weapon testing remains embedded in the Earth and in the bodies of creatures living here.

Millions of people have also been exposed to radiation from nuclear power plant accidents. The largest of these, in Chernobyl in 1986 and

Fukushima in 2011, saw explosions at the failed plants carrying radionuclides downwind just like mushroom clouds, depositing fallout over homes, schools, cities, and areas of food production. Radioactive particles cannot be made “un-radioactive”; you can only move them from one place to another, hence the vast areas of northern Japan filled with plastic bags of radioactive soil from “decontaminated” towns.[23] Among the many fallout particles prevalent in soil downwind from nuclear reactor explosions is $^{137}$Cs, which will remain dangerous for over three hundred years, far outlasting the plastic bags. $^{137}$Cs is particularly good at migrating in an ecosystem once deposited, moving easily from soil into plants into animals and back into soil, and spreading outward via underground or surface water. Decontaminating a town or school in such ecosystems is a temporary measure, as wind and rain will transport more particles from forests and mountainsides back into “decontaminated” spaces. You cannot separate a small zone from its larger ecosystem. We know the names Chernobyl and Fukushima because of the scale of the disasters there, but smaller nuclear reactor accidents have happened regularly since the technology was first invented by the Manhattan Project in 1944.[24]

The production sites of nuclear technologies have also exposed many people to radiation. Since the late 1800s, worldwide uranium mining has seen miners suffering lung diseases from the radon gas given off by uranium ores, and their families suffer from uranium dust tracked back into their homes after work. The processing of uranium both for fuel for nuclear power plants and for weapons left hundreds of sites around the world contaminated with a range of radioactive particles and chemical toxins.[25] The production of plutonium, the reason that nuclear reactors were first invented, has created some of the most radiologically contaminated places in the world.

The people who live in all of these communities are the global hibakusha. *Hibakusha* is a Japanese word that refers to those who survived the nuclear attacks on Hiroshima and Nagasaki; it literally means “explosion-affected person.” In recent years “global hibakusha” is being used to signify all who have suffered the radiological effects of nuclear technologies since 1945. We silo off those affected by radiological events into separate historical incident narratives, but many who live through such events understand their bond with those in the other silos. Natalia Manzurova, a liquidator from Chernobyl, was interviewed a week after the initial explosions of the Fukushima disaster. “Their lives will be divided into two parts: before and after Fukushima,” she understood about the newly emerging hibakusha. “They’ll worry about their health and their children’s health. The government will probably say there was not that much radiation and that it didn’t harm them. And the government will probably not compensate them for all that they’ve lost. What they lost can’t be calculated.”[26] Along with the communities I have described, another cohort of global hibakusha is military personnel who were routinely exposed to radiation during atmospheric nuclear tests. The United States and the Soviet Union, the two most prolific producers and testers of nuclear weapons, each exposed hundreds of thousands of their own troops to nuclear weapons and to radiation. Both conducted single tests in which over forty thousand soldiers participated.[27] The three other NWSs that tested in the atmosphere also exposed troops and test site workers.

As many of these radioactive particles will remain harmful for centuries or millennia, migrating through the ecosystem, more people will encounter and internalize them in the future. Single particles whose half-lives exceed human life spans may pass through several different people. Nuclear waste, laden with a variety of radionuclides, will also far outlast our civilization. Thus, the number of global hibakusha will extend far beyond any current tabulation or imagination. This is the legacy the Cold War wrought.

## Defining the Victims

Scientific and medical constructs of the relationship between radiation exposures and subsequent health effects have been utilized to keep the global hibakusha invisible to science, politics, and history. Our models of how radiation impacts human health were built through studies of the hibakusha of Hiroshima and Nagasaki, begun in the late 1940s and early 1950s. The Atomic Bomb Casualty Commission, established by the United States in Hiroshima and Nagasaki during the American occupation of Japan, and its legacy research institution, the Radiation Effects Research Foundation, jointly operated by the US and Japan, have been conducting a large study correlating the disease burdens and early mortality of the survivors of the two nuclear attacks in 1945 with their radiation exposures.

This is the Life Span Study, begun in 1950.[28] In radiation health communities, the LSS is frequently referred to as the "gold standard" database correlating radiation exposures with health outcomes. It is a robust study that has continued over multiple decades and has included the participation of hundreds of thousands of World War II hibakusha.

The LSS is a landmark study, yet there are problems with its design and use. The first weakness is in the ascribing of dose to each participant. For a study to correlate health outcomes to prior radiation exposures, both details must be accurate. Obtaining health outcomes is straightforward: ongoing monitoring of the health and mortality of the participants yields clear data. Determining individual exposures to radiation in Hiroshima and Nagasaki is more problematic. Exposures occurred during a nuclear attack, and doses had to be estimated years later. Each participant has "dose reconstruction" to ascribe a value to their exposure. The key components in reconstructing dosage is distance from ground zero, and shielding—being out in the open, inside a building, or underground. There is functional certainty about the levels of external radiation in the gamma burst from the detonation as it traveled outward, so if location and shielding are ascertained, it's possible to reconstruct an accurate external dose. Interviews were conducted with survivors to determine an individual's location and shielding. Building a statistical database on interviews and memory adds an imprecise variable to the mathematics. Dose reconstruction has been revised multiple times as more-thorough interviews and more-detailed reconstructions of the radiation field and attenuation of shielding are developed.[29] Even with this imprecision, it is widely agreed that the LSS offers a powerful statistical model relating the exposure of human beings to a single, large burst of gamma radiation with possible disease progressions and mortality.

From the outset, it was decided not to include data about internal exposures from particles that were deposited inside the bodies of the participants in the study, even though it had been well understood by US scientists in the Manhattan Project that internalized radionuclides were deleterious and potentially deadly.[30] There were several reasons for this choice. First and foremost, since the participants were close enough to the hypocenter of the detonation to receive high levels of external radiation, any effects of internalized radiation were presumed to have less health impact than the external exposures. Furthermore, it was impossible to survey a large group of people for internalized particles until the manufacture of fully functional whole-body counters in 1964, and even then it would have taken years or decades to examine hundreds of thousands of subjects. Without such instrumentation, you cannot differentiate who in a group of people has internalized a particle and who hasn't. With external exposures, every person in a specific location will have received a similar dose. With internal exposures, any group of twenty people standing in the same place during a radiological event may experience different outcomes. Internalization would depend on the asymmetric distribution of the particles (as opposed to the symmetric distribution of gamma waves), on who inhaled or swallowed one, and on their personal health and metabolism. The science was essentially impossible, and the more pronounced impact of the external exposures took precedence. Excluding incidence of internal exposures made sense; it was the only way the LSS could produce the quality of work that it achieved. Still, this exclusion was to have profound effects on those who ultimately would become exposed to radiation during the Cold War years.

When radioactive particles deposit downwind of a nuclear weapon test from a fallout cloud, or when they scatter throughout a house when a uranium miner hangs up a work jacket, or when large amounts of radioiodine migrate out from a plutonium production facility, there is an asymmetric distribution: some people will internalize particles and some people will not. It is not possible to predict who will, and almost impossible to know who has. Tools like whole-body counters can assist in analysis, but only very select populations have ever been systematically tested in the decades since their manufacture. When the Bravo fallout cloud descended on the *Daigo Fukuryu Maru,* or on Rongelap, some people internalized particles and some people did not (although all experienced some measure of external exposure from amassed particles). When plumes deposited radionuclides after Chernobyl or Fukushima, they did not uniformly affect the people living below the clouds. After these particles deposit into an ecosystem, some people may escape their effects, some people may encounter (and internalize) them immediately, and others may encounter them years later, not thinking about the presence of radionuclides in the mushrooms they forage. Some will take an indirect route into the human body, such as radioiodine, which is typically internalized by consuming dairy products from farm animals that have eaten contaminated grass or feed. Where in the gallon of milk is the radioactive particle? Who will drink that glass? There is no certainty as to where these particles migrate, where the dangers lie, and who is at risk. It's a risk model directly opposite to that of being exposed to external radiation, in which there can be certainty: being in a specific location at a specific time reveals all. Thus, a primary experience of people in areas of fallout contamination is uncertainty. Is there risk? Are they exposed? Can they protect their children? Any degree of certainty only comes negatively with the presentation of disease, and even then, direct causation is usually indeterminable.

When the United States government authorized the establishment of the ABCC, it seemed common sense that the future of world warfare would include the use of nuclear weapons. The Cold War was a period in which fears of nuclear conflict were endemic. Now, after the Cold War, we can see that didn't happen; there never was a direct use of nuclear weapons between the Cold War protagonists. Populations were not exposed to large bursts of gamma radiation from nuclear detonations. However, millions of people were exposed to radioactive fallout—that actually did happen. And we do not have a medical model to determine what the health outcomes and mortality will be for people whose risks come from internalizing radionuclides. We have the LSS. And so, throughout the Cold War and since, governments and health organizations have trotted out the LSS to assess the disease risks of people exposed to radioactive particles in their ecosystem.

The LSS tells us that external exposures to significant levels of radiation may lead to health impacts, and below that level there is less certainty (and much debate).[31] Thus, in communities where fallout has deposited, where radioactive waste has been dumped into trenches or at sea, and where water flows from streams near mines loaded with uranium tailings, we measure the external levels of radiation to determine if people are at risk. Immediately after the deposition of fallout under a cloud from a nuclear test or an explosion at a nuclear power plant, the collection of particles in one location may be high enough to measure as concerning, but after a few days those particles have been dispersed by wind and rain, and thus externally measurable levels steadily decrease. Weeks, months later, the particles will have embedded deeper into the ecosystem and the measurable levels may be very low. To address the worries and care for the health of those in the affected area, we apply the mathematics of the LSS: Are the levels of external radiation high enough to predict future health burdens? That is the wrong question to ask and the wrong tool with which to craft a response. The LSS was developed as a database to inform us about risk and health impacts from large bursts of external radiation; it tells us little about the consequences of large depositions of rapidly dispersing particles, or what the health outcomes are from internalizing one. But it's what we have, so, we use it.

Invoking the LSS invariably tells experts that people exposed to fallout have exposures below levels that correspond to increased risk of disease. It is true that their exposures to external radiation are typically low; however, that's not where danger lies. Radioactive particles are still in the ecosystem around their homes, in their children's schools, and in their gardens, farmlands, and forests. While measures of external radiation can be extrapolated —levels in one part of a schoolyard seeming likely to be close to those in another part of a schoolyard—particles will be asymmetrically distributed, and so low readings in one place tell you little about possible readings just a few meters away. Wind and rain tend to flush particles downward in a landscape. There will typically be more particles collecting in the gutters on the sides of roads than in the middle of the road, or more particles in the streams running off of a field than in the air above the field. Any model of risk from internalizing radionuclides that would be drawn up for a space would have to be specific to that space and the time of its measurement: an afternoon rain could redistribute the risk. The potential for a person to internalize a particle in a contaminated ecosystem also varies. Particles have mass and so typically settle on the ground rather than linger in the air. Children are closer to the ground than adults, tend to sit there more frequently, and often put things from the ground in their mouths. Thus, children are more likely to internalize particles in a setting than adults. Still, one child may and their playmate may not. Who among the radiation-exposed will also become among the radiation-affected? The uncertainty about this progression can in itself become emotionally debilitating, especially for parents.

Utilizing the LSS only occurs in communities where the rights and health of the people are sufficiently respected to actively manage their anxieties. In many nuclear test site regions, especially in colonial or postcolonial spaces, no assessments or information was provided. A quick survey of test locations reveals the structural nuclear colonialism in their siting. Two NWSs did not test even one weapon within their own national borders. Several nations tested weapons, especially thermonuclear weapons, in colonial states or trust territories under their political control in Oceania rather than domestically. Even when testing was done within national borders, sites were located near minority populations with little political power, such as Kazakhstan in the former Soviet Union, Nevada in the United States, and the Xinjiang Uyghur Autonomous Region in China. Test sites were never located near centers of power or concentrations of ethnic, racial, or social elites. No plutonium production facilities were built near capital cities or financial centers. Those irradiated were selected specifically because of their inability to resist. In developed nations where citizens had agency and rights, later distress over the disease load borne by these populations was dismissed by citing the LSS. In colonial or postcolonial spaces like Kiribati, no one bothered to pacify the exposed.

## Nuclear War in the Cold War

Our histories of the Cold War fixate on the war that was not fought. Despite the arms race, despite the political tensions, despite the hair-triggered mutually assured destruction, nuclear war was successfully deterred. John Lewis Gaddis called this the "long peace."[32] Recently, scholars have focused on the many regional conflicts and anticolonial wars that were sucked into the Cold War binary, detailing the never-ending military conflicts that, in part, proxied for the superpower face-off. Rarely, if ever, is nuclear weapon testing mentioned in Cold War historiography. When we say the Cold War nuclear conflict never happened, we are really saying that it didn't happen to us. It is a privileged perspective. For people living near atmospheric nuclear testing sites, it did happen. In the lives of those in the Marshall Islands, in East Kazakhstan, in Kiribati, and in French Polynesia, nuclear war was not deterred. For those living in the "5,000 square mile" death zones, this was not an imaginary war—it was a limited nuclear war.

There are multiple reasons that we cannot see that the Cold War was actually a limited nuclear war. We define warfare as the direct use of weapons against an enemy. Cold War nuclear strategists moved past this definition: nuclear attacks were designed to kill and sicken populations far from target locations through the effects of large fallout clouds from high-yield weapons. Tests of these same weapons inflicted these exact effects on downwind populations from test sites, just as they would on downwind populations in warfare. Many people were exposed to and suffered from nuclear weapon effects specifically intended to harm human beings.

Another reason we can't see this as a limited nuclear war is that those harmed were not politically powerful enough for the attacks to bear consequences for the attackers. They were not attacking enemy populations; they were attacking populations under their own care.[33] To minimize their liability, they focused the attacks on colonial, postcolonial, or marginal populations: "nuclear subalterns."[34] The United States tested nuclear weapons in Nevada, upwind of populations made up primarily of Mormons, Native Americans, and Hispanic farmworkers, but they never tested high-yield, thermonuclear weapons there: all of the H-bombs were tested in Pacific territories filled with noncitizens. The Australian government would not allow the British to test thermonuclear weapons in the traditional Aboriginal territories where the first British fission weapons had been detonated, so the larger weapons were tested in Kiribati. The Soviet Union tested all kinds of weapons in Kazakhstan, where, by official definition, only "nomadic" people lived. Each side harmed people under their own care who had no recourse. In the case of the US and USSR, which conducted 84.87 percent of weapon tests between them, nuclear weapon testing became a way of signaling strength and brutality to each other.[35] They engaged in what Liddell Hart would call "indirect warfare," demonstrating the ferocity of their arsenals, delivery systems, and intentions without risking direct conflict, harming only people that were, to them, expendable.[36]

This is an uneven history. In some instances, people were forcibly removed from their homes because of contamination, like the "quiet people" evacuated on US ships after the Bravo test. In such cases, families were forced to abandon their property and belongings, live in temporary housing, be resettled as refugees in new communities, or be returned to their former homes after sloppy remediation. Nuclear scientist Hiroaki Koide has remarked, "Staying in contaminated areas hurts the body, but evacuation crushes the soul."[37] Sickness, death, displacement, loss of property, abandonment to continued habitation in radiologically contaminated homes: the history of nuclear testing is the history of a limited nuclear war.

## Killing Our Descendants

Nuclear weapons exert violence across distances. The limited nuclear war that I just described saw violence inflicted on lands distant from the actual location of the weapons' detonations: fallout clouds carried radionuclides to deposit hundreds, thousands, or tens of thousands of kilometers away. A separate nuclear catastrophe threatens to exert violence into distant time and against countless generations of our descendants. This is the disposal of vast measures of highly radioactive waste from nuclear technologies, especially the hundreds of thousands of metric tons of spent nuclear fuel rods from our production of both plutonium and electricity. This waste is laden with the most toxic materials on Earth and will confront future generations with radiological risks beyond ten times longer than human societies have practiced agriculture.

This is not something that might happen; this is something that has already happened. It is a global legacy currently sitting in spent fuel pools and dry storage casks, waiting. We knew throughout the period we generated this waste that there was no method for its disposal—in dozens of countries. We manufacture more every day. The best plan we can devise is to bury it deep, deep, deep underground. We pretend there are places on this planet that can be separated from everywhere else. We intend to build geological repositories 500 m below the Earth's surface, encapsulate the spent fuel in canisters, bury them in holes, and seal the whole mess up with clay. Not once, but dozens of times—in dozens of places—all around the world. We tell ourselves that we can do this perfectly . . . repeatedly. We turn a blind eye to the trail of imperfections that has characterized all human endeavors, that brought us into this very situation.

Spent nuclear fuel consists of uranium fuel rods that have "burned" in nuclear reactors to manufacture either plutonium for nuclear weapons, or electricity. Nuclear reactors were invented to manufacture plutonium, and were operated for over ten years in three countries before contributing electricity to any public grid (done first in the USSR).[38] Once the fuel has been used, or "spent," it becomes waste. The spent fuel rods contain many radioisotopes, including uranium and plutonium, which will remain highly radioactive for over one hundred thousand years and will generate excess heat for the first several thousand years. Fuel rods are typically used for about three years in reactors and then must be contained for longer than human history. There are currently between 300,000 and 400,000 metric tons of this spent fuel on Earth, along with large amounts of other forms of high-level radioactive waste.[39]

None of the thousands of generations that will share their world with this waste will receive any benefit; they will have only burden. Yet we convince ourselves that they will be safe if they just listen to us and follow the instructions we will leave at the repositories: we who generated the waste with no plan for its disposal, we who enjoyed the tiny benefits it provided, we who have put them in this position. If they just listen to us, we tell ourselves, we can protect them. We imagine that they may be irrational and we may have to scare them to keep them from digging the waste up; we may have to devise mythologies or religions that can pass down our instructions to them; we plan to design monuments that will direct them to our information kiosks, where they can receive details from us about how to avoid disaster. We . . . imagine that *they* may be irrational.

We are not seeking the best single place on Earth to bury this waste: we are seeking dozens of places in the specific countries that generated portions of that waste. Each nation that made nuclear weapons or used nuclear power to generate electricity must bury its own waste. Even though we are engaging in millennia-long tasks, seeking to protect thousands of generations who will have no allegiance and perhaps no knowledge of the different nation-states that generated and buried the waste, we are convinced that we must dispose of it within the political units of those nation-states because . . . we are appeasing the necessities of our own socially and politically constructed world. It's who we are. We can't conceive of acting outside of our constructs, but we can imagine it will go perfectly—as long as humans in the future pay attention to our instructions.

The disposal of this waste, in the most effective and responsible way possible, is perhaps the largest challenge to ever face the human race. Failure to meet this challenge will subject thousands of generations of human beings and other creatures to extreme dangers. The manufacture of this waste is the most ecologically significant event caused by living creatures in the long history of the planet. Unlike asteroid impacts that have led to extinctions, the risk from this waste will be ongoing, enduring long past any specific disaster affecting one generation along the way. It is, by definition, temporal violence, striking at the future bodies that will grow on the Earth.

## De-National History

There have been many books exploring the history of nuclear weapon testing, radiation exposures, and the legacies of Chernobyl, Fukushima, and other nuclear disasters. Based on how we narrate war and politics, those histories have often focused on the radiological legacies of specific nations. They are histories of US nuclear testing, British nuclear testing, Soviet or Japanese power plant disasters. However, the nature of these events, the distances their effects travel, the penetration of their legacy radionuclides into deep time all make this a global history. When we look at the victims of Soviet testing in Kazakhstan, we can reduce their number to a tragic but understandable level. When we talk about those impacted by British nuclear testing, the locations seem contained: a small area of the desert in Australia and some islands. It is when we de-nationalize and survey this as a global history that we can begin to see the limited nuclear war hiding behind the long peace. As a group of national histories, it has been dismissed; as a global history, it is profound. When we focus on the experiences of human beings exposed to radiation from fallout particles rather than on elite discourse about deterrence and geopolitics, we grasp the actual role of nuclear weapons in the Cold War: the embodied history.

Kate Brown, the scholar of Cold War plutonium production and the human impact of the Chernobyl disaster, has written that "There ought to be a new frontier of scholarly inquiry, one that learns to read bodies as historical texts so as to re-create historically voided bodies living on contaminated landscapes in a way that does not dismiss bodies in pain."[40] This new frontier must not be distracted or bogged down by political ideologies and national histories. Human bodies are of a species, and this history is a species history whose political location is Earth. When it is seen as global history, the full impact becomes visible—the radiological harm no longer appears episodic, but systemic. We must hold nations responsible and detail their actions: as the fallout particles are transported around the world, so too should be our gaze.