Unmaking the Bomb:
Waste, Health, and the Politics of Impossibility at the Hanford Nuclear Reservation

By

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Abstract

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This dissertation explores the politics of waste, health, and remediation at Washington State's Hanford Nuclear Reservation. The most contaminated nuclear site in the nation, Hanford is engaged in the largest environmental cleanup in human history—legally required to implement protective measures that will remain effective for 10,000 years. Informed by eighteen months of ethnographic fieldwork and more than 100 in-depth interviews with Hanford workers, managers, and area residents, this project explores how nuclear remediation is made possible despite its inherent uncertainties. Through four empirical chapters, I make the case that nuclear waste is not socially inert, but distinctly productive. Just as above-ground weapons testing produced the official script for American nuclear disaster with its televised detonations and duck-and-cover drills, I argue that the contemporary spectacle of remediation works to re-define the terms of nuclear citizenship and national security in the face of the nation's enduring waste. Thus, cleanup projects at former weapons sites like Hanford articulate a new social contract for nuclear threat in the post-Cold War era—one that defines the conditions of "livable" exposure and "acceptable" contamination, highlighting particular hazards while rendering others invisible.

For my Grandad, Walter Edward Lindsley Sr.

who loved eastern Washington and the Columbia River

and who worked at Hanford for a time

1922 – 2013

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ACRONYMS

ABCC	Atomic Bomb Casualty Commission
ABSS	Atomic Bomb Survivor Study
ACHRE	Advisory Committee on Human Radiation Experiments
AEC	Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
ARRA	American Recovery and Reinvestment Act
BEIR	Biologic Effects of Ionizing Radiation
CNI	Committee for Nuclear Information
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
DST	Double Shell Tank
DOE	Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
EPA	Environmental Protection Agency
EM	Office of Environmental Management
ERDF	Environmental Restoration Disposal Facility
HAB	Hanford Advisory Board
HPT	Health Physics Technician
IBC	Integrated Biological Control
ICRP	International Commission on Radiation Protection
LSS	Life Span Study
NERP	National Environmental Research Park
NRC	Nuclear Regulatory Commission
RME	Reasonable Maximum Exposure
RPG	Radiation Protection Guide
SST	Single Shell Tank
WTP	Waste Treatment Plant
USFWS	United States Fish and Wildlife Service

ACKNOWLEDGEMENTS

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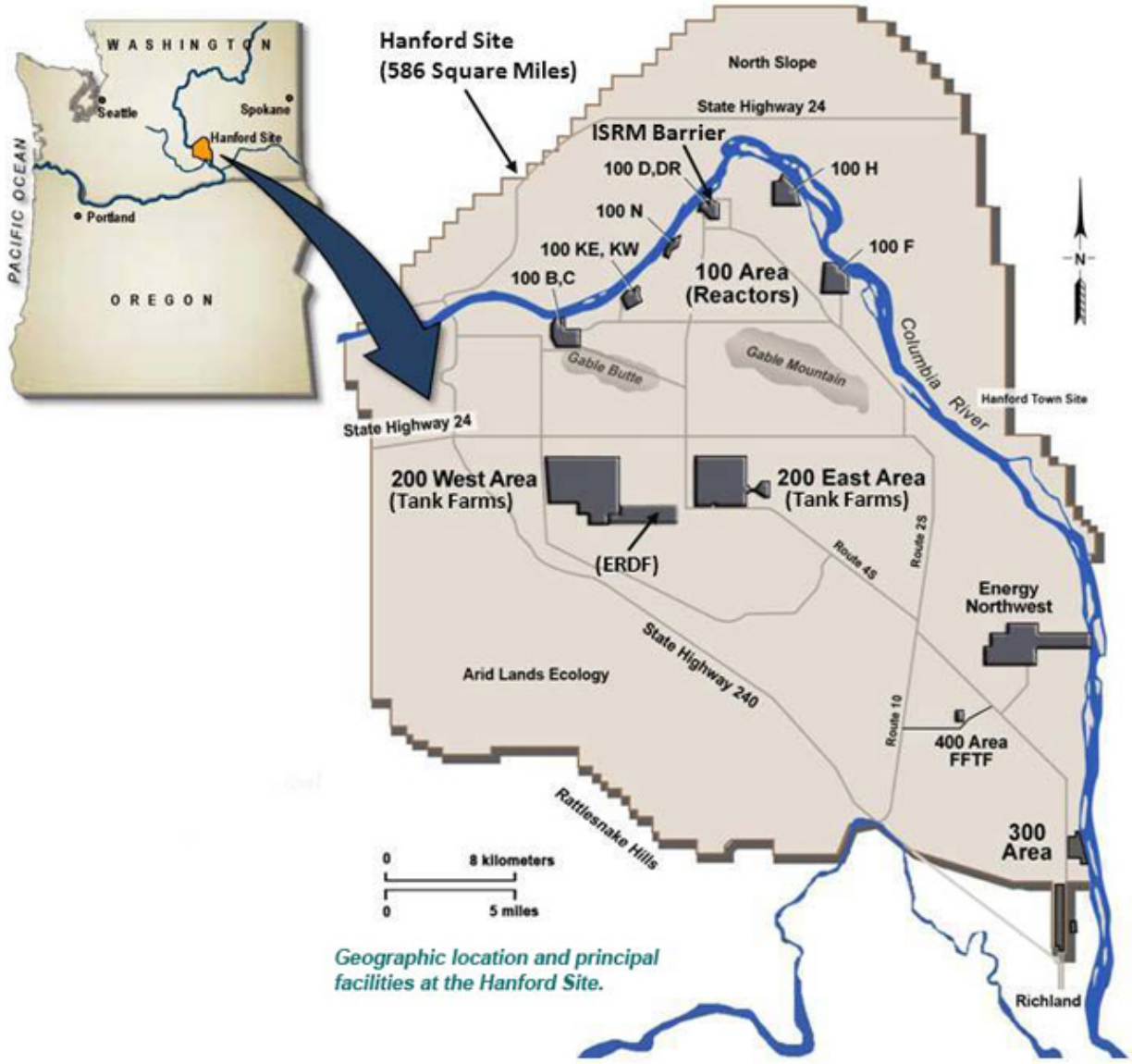


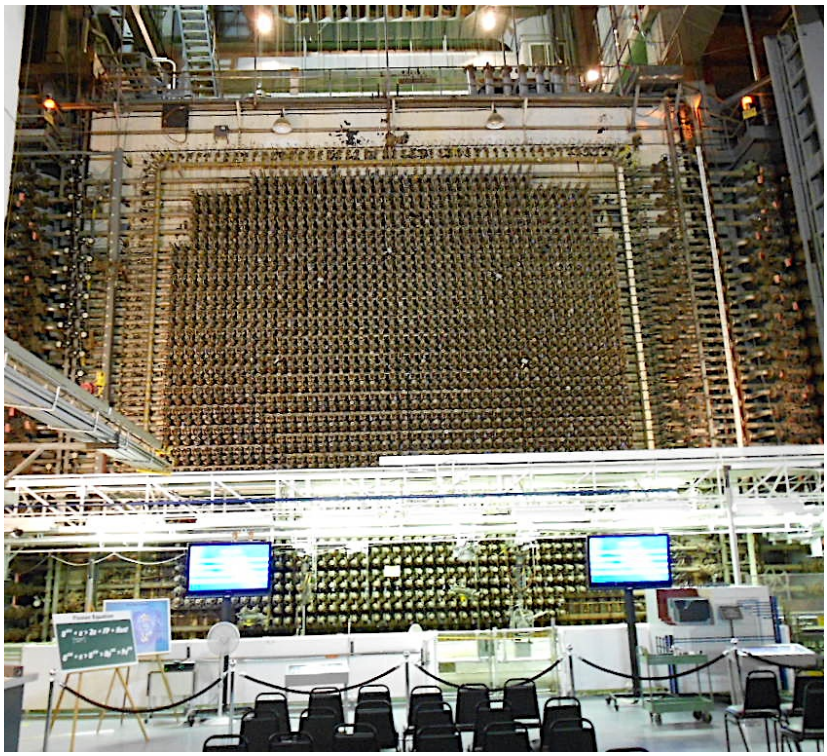
Geographic location and principal facilities at the Hanford Site.

2. Map of the Hanford Nuclear Reservation (DOE 2015)

Note that Richland, Washington is in the bottom right hand corner

PREFACE

In the Fall of 2004, I found myself standing at the center of a nuclear reactor. The core in front of me was more than three stories tall, an enormous graphite cube punctuated by thousands of thin aluminum tubes (Image 3). Beneath my feet, concrete floors extended outward to mint-green walls—painted with lead-based paint "to block any residual radioactivity," my guide said. As I stared at the reactor's face with its complex matrix of tubing and wires, I felt my throat start to thicken with tears. Self-conscious, I took a deep breath and tried to shake the feeling, but the impact of the space was too great. I was overcome by the weight of what had emerged from this reactor, the multi-millennial echoes that still emanated from its walls. So much had changed because of this place. So much began right where I stood.



3. B Reactor Core (Tinker 2012).

The reactor was simply called "B." Built in 1943 as part of the Manhattan Project, it was the first facility in the world to make plutonium at an industrial scale. It fueled the "Trinity" bomb in Alamogordo, New Mexico and then "Fat Man" a few weeks later in Nagasaki, Japan.[1] After World War II, it continued to make plutonium for nearly twenty-five years, processing millions of tons of Uranium fuel.

[1] The Hiroshima bomb, code-named "Little Boy," was fuelled by enriched Uranium made by its sister facility, the Oak Ridge facility in Tennessee. All three bombs (Trinity, Fat Man, and Little Boy) were assembled by scientists at the Los Alamos site.

B is one of nine full-scale reactors at the Hanford Nuclear Reservation, a weapons complex in southeastern Washington State. Occupying 586 square miles of land and a sharp elbow of the Columbia River, Hanford is a hot, dry landscape with sagebrush-scented air in the rain shadow of the Cascade Mountains. This oft-forgotten arid region of the Pacific Northwest was the heart of American plutonium production for more than four decades. By the time it closed its final reactor "N" in 1987, the site had manufactured 67.4 metric tons of weapons-grade plutonium—more than 60% of the material in U.S. nuclear arsenal (Gephart 2003).

In the process, Hanford had also created the most contaminated nuclear landscape in the western hemisphere (Niles, 2014; Gephart, 2010). Since production began at the B reactor in 1943, an estimated 450 billion gallons of liquid nuclear waste have entered the reservation's soil and water table, bioaccumulating in plants and animals (including humans), and forming a network of toxic groundwater plumes that communicate with the Columbia River. Home to more than two thirds of the U.S. high-level nuclear waste inventory, Hanford is currently undergoing the largest and most expensive environmental remediation project in human history—tasked with managing, mitigating, and containing the byproducts of Mutually Assured Destruction.[2]

Though my Grandad worked at Hanford during the Cold War and my Mom grew up within 50 miles of the site, I only learned of its existence a few months before my first visit to the B reactor.[3] At twenty-four, I had spent the past few years traveling in Europe and Latin America and then floating from job to job—teaching English in Prague, working on a ranch in Colorado, serving food and coffee in a tiny California café. In May of 2004, I was broke, living at home with my Dad, and had just been accepted to graduate school at the University of Oregon. When friends in Seattle offered me their spare bedroom, I decided to move north and work for a few months, taking the first job I could find. That job turned out to be canvassing door-to-door for WashPIRG and the summer's campaign was about Hanford.

It is surprising how little one has to know about an issue in order to canvass on its behalf. In fact, my managers at WashPIRG asked that we didn't stray from the "rap," a one-minute script that each canvasser memorizes and repeats word-for-word at every door. When I eventually became a manager myself, I told new recruits the same thing. "Stick to the formula," I'd say, "that's what works." From May to August, I covered the state of Washington saying the same rehearsed speech over and over. "Hi, I'm Shannon. I'm from WashPIRG, Washington's public environmental group. Have you heard about the Hanford Nuclear Reservation?" I gathered signatures and donations, talking to literally thousands of people about Hanford without knowing much more than my official blurb and a few factoids. For awhile, I joined the camping canvass

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[2] At present, Hanford's waste inventory includes, "more than 50 million gallons of high-level waste in 177 underground storage tanks, 2,300 tons of spent nuclear fuel, 12 tons of plutonium in various forms, about 25 million cubic feet of buried or stored solid waste, about 270 billion gallons of groundwater contaminated above drinking water standards, spread out over about 80 square miles, more than 1,700 waste sites, and about 500 contaminated facilities" (Hanford Natural Resources Trustee Council 2013).

[3] Because my Mom's hometown of Selah was located within a 50-mile radius of the site, it often shows up in declassified reports about area contamination. At times, according to these reports, Selah and the towns that surround it registered higher levels of radioactivity than Hanford's border.

in the San Juan islands, where we knocked on doors all day and drank beer around the campfire each night.

Though I could say the rap in my sleep, and certainly felt concerned about Hanford's waste, I would not have called myself an activist. I cared about environmental issues and hoped the campaign's initiative would pass (it did), but I didn't feel personally invested. Canvassing was just a job for me, an often difficult and uncomfortable one at that. Almost no one actually *likes* to find a canvasser at their door. During that summer, one of my co-workers was held up at gunpoint, another was chased down the road with a car, and one of my own crewmembers was punched in the face. I wasn't canvassing because I felt passionate about the issue; it was simply a way to pay my expenses for a few months. Hanford felt far away from my life in Seattle.

At the end of the summer, I returned to California where I borrowed my sister's VW van, packed it full of my things, and drove up to graduate school in Eugene, Oregon. I started working on a master's thesis about ecotourism in Costa Rica, making plans for my first research trip there. Before I left, however, I noticed an online advertisement for an upcoming public tour of the Hanford site. On a whim, I registered for one of the few spots remaining and drove the five and a half hours north. It turned out to be a life changing decision.

The tour lasted about five hours, much of which was spent on a bus traveling between areas of interest on site. I was easily 25 years younger than my fellow tourists and seemed to have a different set of politics as well. Our guide, a former Manhattan Project engineer in his eighties with white hair and a ready smile, told jokes and war stories as we drove. It was clear that he enjoyed his role as a docent, laughing and recalling the excitement of production years. At first it felt comfortable to listen to this happy elderly man talk about his youth while we rode in our air-conditioned bus. However, I grew tense when he began referring to Japanese people as "Japs" in descriptions of his early work on site.[4] Each time he did this throughout the rest of the day, I looked at others around me for a reaction—a raised eyebrow or surprised look, even a quiet laugh and shake of the head. But no one flinched. In fact, no one's facial expression seemed to register the term at all. It was disorienting enough that I thought quietly to myself, "Where am I?"

As we continued to drive, I was struck by how empty and, really, how *normal* the landscape looked. After a summer of warning Washingtonians about Hanford's extreme contamination, I had expected that I would at least be able to *tell* that bomb-making had happened here. Instead, what I noticed was the subtle beauty that accompanies aridity: a landscape of muted colors with such complexity and depth that its greys and browns were vivid as a sunset. At times, our tour guide interrupted his stories to point out mule deer, coyotes, and raptors outside our windows as tumbleweeds drifted lazily by.

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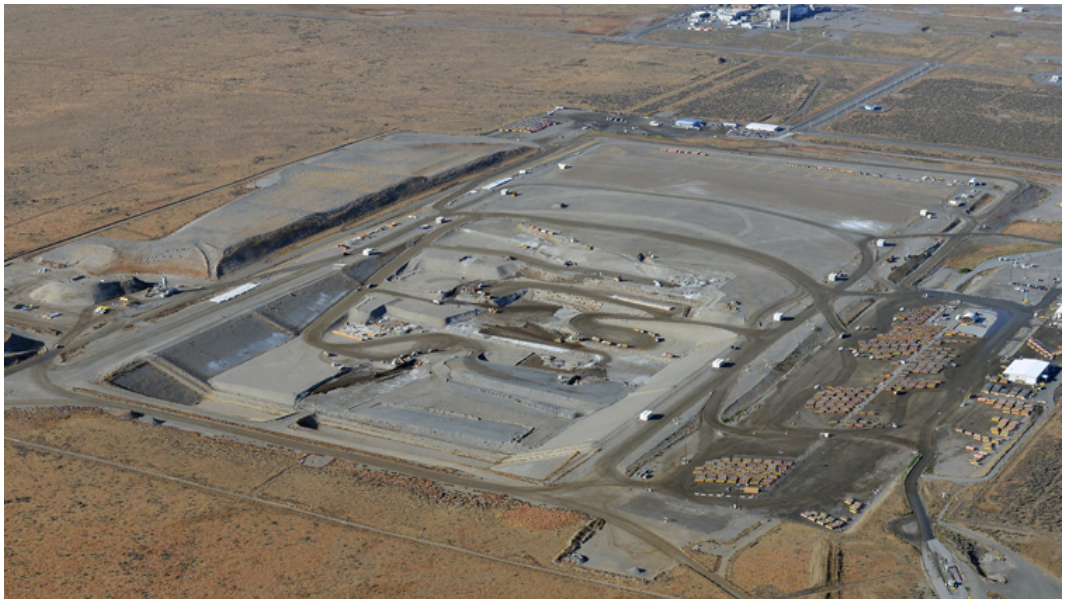
[4] I continue to take Hanford's public tour every few years. Though this first guide in 2004 was the only one to say "Japs," overt racism has still infused subsequent tours. On my most recent tour in 2013, our guide told us that Native Americans used to live on the site. As he described the end of cleanup, he said, "so we'll pat some dirt over it, sprinkle a few arrowheads on it, and call it good!" before laughing uproariously. Others on the bus laughed too. When I told one of the people who helped design the Hanford public tour about this, she was horrified and said she would do her best to address it.

About half way through one of these longer scenic stretches, we arrived at the Environmental Restoration Disposal Facility, or ERDF as it is commonly known (pronounced "Erdiff"). Located at Hanford's center (see map), ERDF was built in 1996 to house the low-level nuclear wastes generated by cleanup activities on site. At 107 acres and a holding capacity of 18 million tons, it is one of the largest nuclear disposal facilities in the world (DOE 2015) (Image 4). When our bus stopped at the edge of its enormous pit, two workers came inside.[5] They held up poster boards that described the disposal process and showed us samples of the material that they used to line each disposal "cell." I remember being struck by how thin the lining material was (less than an inch thick), as the workers described its impenetrability. I wanted to ask them, "wait, doesn't this material have to contain nuclear waste for *thousands* of years?"—but didn't. I again felt a sense of disorientation as I realized that "cleanup" at Hanford didn't mean that the amount of waste changed or somehow went away. Rather, it appeared that remediation simply meant digging up contamination next to the Columbia River and then re-burying it (with a liner) near the center of the site. Even the name of this place was confusing: Environmental Restoration Disposal Facility. I had never considered that *restoration* and *disposal* could be synonymous or complementary terms.



4. Environmental Restoration Disposal Facility (ERDF) (DOE 2015a).

Next, we drove past Hanford's "Tank Farms" where about 54 million gallons of high-level nuclear waste are stored in 177 underground tanks. Though it is hard to say with certainty, the Department of Energy (DOE) estimates that these tanks contain about half of the chemicals and

[5] On subsequent tours, we have been allowed to exit the bus and watch as trucks deposit waste at ERDF. It is a humongous trench, and the trucks looked tiny from our vantage point high above. I remember feeling both interested and a bit anxious as I listened to workers describe the process I was watching. Because Hanford is a very windy place, I couldn't help wondering what was in the dust around me as workers described the materials being interred below.

radioactivity on site (Gephart 2003). When they were built the 1940s, the tanks were envisioned as short-term storage facilities. In fact, the first 149 tanks (called Single Shell Tanks, or SSTs) were designed to last only 10-20 years. Now decades past their design life, the SSTs have leaked an estimated 1.5 million gallons of high-level nuclear waste into the surrounding soil and groundwater (WA Dept. of Ecology 2015). From 1968 to 1986, Hanford engineers built another 28 tanks, this time adding an additional shell to guard against leaks (these are called Double Shell Tanks, or DSTs). Though DSTs were designed to hold waste for a relatively longer period (25-50 years), they have begun to feel the weight of time and toxicity as well. The first DST leak was reported in October 2012.

Though its statistics are impressive, the Tank Farms' visible landscape is not. From the bus window, it simply looked like a large, flat industrial area with pipes (called "risers") sticking out of the ground at various points (Image 5). There are many challenges associated with tank waste management, we were told, and this landscape demonstrated one of them: the waste is not easy to access. Removing tank waste means pumping it through the thin risers that we could see, some of which were only 4 inches in diameter (Gephart and Lundgren 1999). Because much of the waste is not fluid, but closer to peanut butter, salt cake, or even very hard cement, the physical act of taking waste out of a leaking tank is a difficult, dangerous, and expensive proposition. Paradoxically, the process of removing waste can actually make leaks worse, as solvents added to facilitate pumping increase pressure on internal cracks and fissures. Furthermore, one cannot remove a tank's liquid without removing its sludge and solids as well. Without the liquid, thicker wastes can generate excessive heat and radionuclides can become concentrated enough to "go critical" and explode.

5. The surface of one of Hanford's Tank Farms (Mulvany 2014).

Hanford's tank waste is unlike any other material on the planet. It is complex, uncertain, and ever changing as its chemicals and radionuclides interact, congeal, and mutate. By law, this

waste must be removed, processed, and transformed into glass logs through a process known as "vitrification." However, it is difficult to build a vitrification facility for a waste form that is constantly changing. Indeed, Hanford's current vitrification project, known as the Waste Treatment Plant (WTP), was put on hold in 2013 after whistleblowers pointed to design flaws that could have produced an explosion larger than the one at Fukushima (Nazaryan 2013).

The tour's *pièce de résistance*, the B reactor, was our final stop for the day. Hanford's flat topography allowed us to see its distinct outline from miles away and I could feel anticipation building in the bus. Some of my fellow tour goers talked about family members who had worked at the B reactor as others peered out at its iconic rectangular form and tall stack (Image 6). Upon entering the reactor and passing through a short hallway, we walked into the cavernous room that contained the reactor's core. The site of it was enough to stop me in my tracks.

6. Hanford's B Reactor (Mulvany 2014).

Standing in front of the B reactor's face, it was as if the abstract words that I had been repeating while canvassing all summer rearranged themselves into something concrete. Or, perhaps it was an embodied recognition of how the abstract and concrete represent a constitutive coupling. When I brought my partner Adam to this place nine years later, he likened it to standing on the rim of the Grand Canyon, and I understand what he means. This wasn't a transcendental experience of technology, I was not Thoreau reveling in the power of the train (Marx 1964; Thoreau 1910). Rather, what I felt was an intense physical reaction to the scale of this place, the way in which the bomb's social, geographic, and temporal impact had become so great as to

surpass the thinkable. At the same time, I was also deeply aware of the bomb's immediacy and concreteness, the lives it had ended, the bodies and landscapes it had changed.

When the tour ended, I drove back home to Eugene and began this research project. Now more than ten years and two graduate degrees later, I am still pondering Hanford's constitutive contradictions. Just as life's elementary matter is both particle and wave, this dissertation considers the ways in which the bomb is both discrete and fluid. It examines how nuclear materials unsettle historically constituted divisions between the social and individual, natural and unnatural, rational and imaginary. At once immediate and endless, the bomb's material traces disrupt the notion that time moves unidirectionally. Thus, the stories that this dissertation tells exist in dialectal relation between the "here-and-now" and "what has been" (Benjamin 1999). They attend to the "ghostly matters" that remain present even when rendered absent, and consider such hauntings to be integral to social life (Gordon 2008).

INTRODUCTION

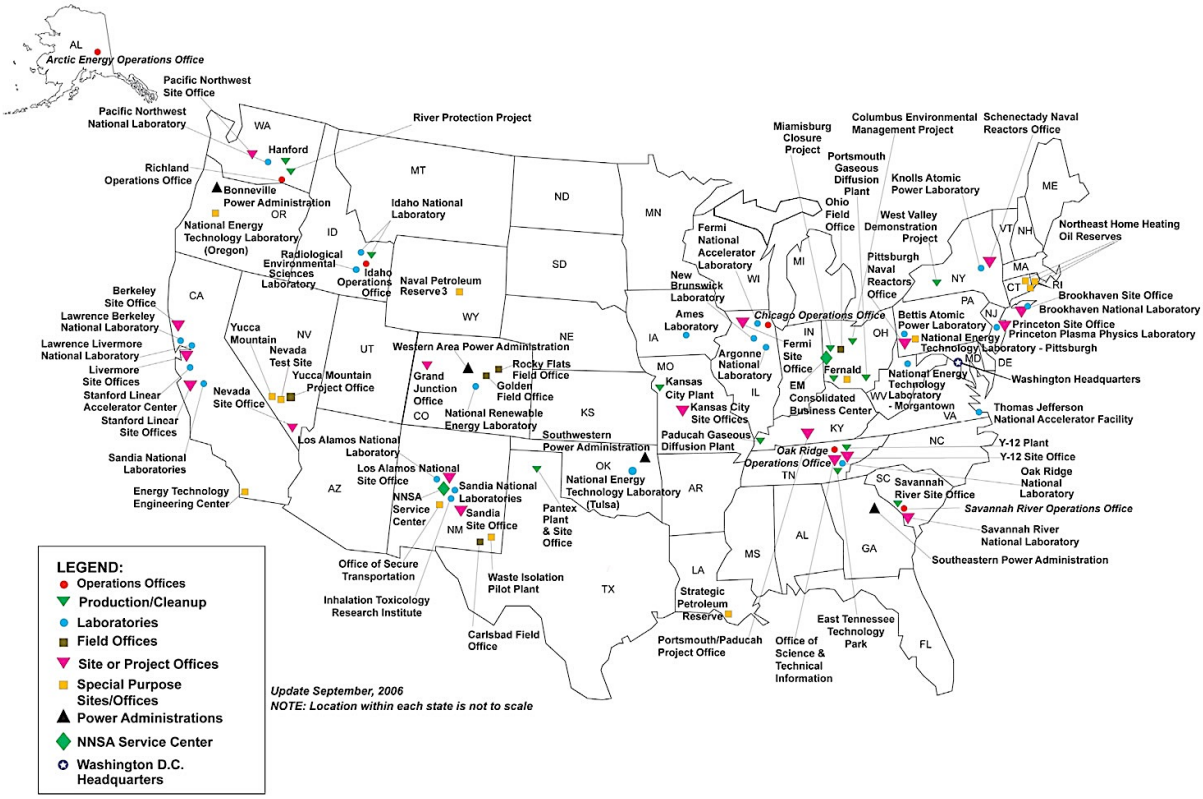
Alice laughed. "There is no use trying," she said, "one can't believe impossible things."

"I dare say you haven't had much practice," said the Queen. "When I was your age, I always did it for half an hour a day. Why, sometimes I've believed as many as six impossible things before breakfast."

—Lewis Carroll, Through the Looking Glass and What Alice Found There

UNMAKING THE BOMB

By the end of the Cold War, nuclear weapons production had become a trillion-dollar industry (Schwartz 1998). As Manhattan Project physicist Niels Bohr predicted in 1939, making the bomb "turn[ed] the United States into one huge factory" (Rhodes 1986: 294). Indeed, by the time the Soviet Union formally dissolved in 1991, the U.S. nuclear complex occupied 3,300 square miles of land and had created massive weapons-based economies surrounding production facilities in Oak Ridge, Tennessee; Richland, Washington; Los Alamos, New Mexico; Aiken, South Carolina; Amarillo, Texas; Idaho Falls, Idaho; Rocky Flats, Colorado; and hundreds of other smaller sites (O'Neill 1998) (Image 7).



7. Department of Energy Facilities Map (DOE 2015b).

However, this vast industrial infrastructure was never designed to *stop* making nuclear weapons. There was no end point in the nuclear deterrence model. Peace, former DOE advisor Bob Alvarez explains, was a "profoundly disruptive thing to a system that had never envisioned stopping. The United States and Russia, and especially the people running their nuclear weapons industries, never thought about stopping and what that means. There were no contingencies. They just thought this would go on forever" (2009).

Thus, as the Cold War came to a close, the U.S. government began the previously unthinkable task of post-production accounting. In 1989, Secretary of Energy James Watkins created the Office of Environmental Restoration and Waste Management[6] with the express purpose of "mitigating the risks and hazards posed by the legacy of nuclear weapons production" (DOE 1997: 1). In 1993, Watkins' successor Hazel O'Leary launched a department-wide Openness Initiative, revealing thousands of wartime human radiation experiments and intentional contaminant releases (Welsome 1999).[7] In 1995, the National Defense Authorization Act required that the Department of Energy provide a detailed analysis of weapons-based waste and contamination. In response, the DOE produced a series of reports with titles like, *Closing the Circle on the Splitting of the Atom: The Environmental Legacy of Nuclear Weapons Production and What the Department is Doing About It* (1996a), *Estimating the Cold War Mortgage: The 1995 Baseline Environmental Management Report* (1996b), and *Linking Legacies: Connecting the Cold War Nuclear Production Processes to their Environmental Consequences* (1997), to name a few.

Collectively, these reports address the material remains of a national security strategy that privileged the immediate threat of Soviet attack over the slow violence of environmental contamination (Nixon 2011). The result of these Cold War policies, they find, is a distinct "geography of sacrifice" (Kuletz 1998), requiring a nation-wide cleanup effort likely to cost more than the nuclear arsenal itself (Schwartz 1998; DOE 1996b). However, even as they emphasize the magnitude of environmental impact associated with weapons development, these reports also position cleanup efforts as the manageable second half of the nuclear production cycle.

For example, in the introduction to *Closing the Circle on the Splitting of the Atom*, Thomas Grumbly[8] likens the story of American nuclear production to the "full sweep of a clock face" (DOE 1996a: ix). At noon, he writes, the world's first atomic bombs were born, followed by Cold War geopolitics and weapons manufacture from 2:00 until 5:00 pm. Early evening marked the close of the Cold War and the majority of its weapons programs—the Berlin Wall crumbling at around 5:30, in time for U.S. nuclear remediation to begin at 5:45. Looking forward, Grumbly envisions the final six hours and fifteen minutes of the nuclear project in which contaminated landscapes are scrubbed clean and radioactive wastes stored securely. At midnight, he imagines,

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[6] Now called the Office of Environmental Management (EM).

[7] O'Leary was outspoken in her campaign to change the culture of nuclear secrecy in the United States. As a sign of her intentions as Secretary of Energy, she changed the name of the Office of Classification to the Office of *De*classification. "The Cold War is over," she told a press conference on December 7, 1993, "we're coming clean" (Welsome 1999: 424). O'Leary's Openness Initiative declassified and reviewed more than three million documents about nuclear science, manufacture, and testing and prompted a series of public hearings and the formation of the Advisory Committee on Human Radiation Experiments (ACHRE).

[8] Grumbly was Assistant Secretary of the DOE's office of Environmental Management from 1993 to 1996.

the hands of nuclear time will return to their original position, sealing the U.S. atomic endeavor with a neat click.

Detailing plans for remediation, *Closing the Circle* extends Grumbly's metaphor, envisioning nuclear production from cradle to grave as a circular rather than linear process. Selecting a circle as the shape of nuclear progress points to several DOE mandates for remediation. First, and most evident, is that of containment. By "closing the circle," the state effectively re-seals Pandora's box, asserting control over runaway radionuclides. Second, circular imagery portrays time as cyclical, suggesting that movement toward complete remediation is also progression towards an original state. As such, advances in nuclear technology facilitate a return to edenic nature, painting science as an agent of both progress and purification and allowing narratives of production and erasure to entwine. Ultimately, by naturalizing nuclear production as cyclical—expanding and retracting, moving forward while forever returning to itself—the Department of Energy not only renders remediation attainable, but inevitable; as certain as the passage of time.

Of course, such narratives of containment belie the critical fact that complete remediation is simply not possible. Nuclear cleanup cannot recover a pre-bomb past. Weapons production and above ground testing spread radioactive particles to every corner of the globe, infusing the entire biosphere with trace elements of the bomb. So too, the magnitude of weapons-based contamination and the longevity of its radionuclides make it impossible to design cleanup procedures that could truly close the atomic circle. Plutonium, for example, has a half life of about 24,000 years meaning that it will continue to irradiate planetary soils for approximately ten times that interval—in other words, until about the year 241,943.[9]

Even the federal government's own legal mandates for remediation exceed the realm of the possible. Superfund legislation[10] requires that cleanup projects implement protective measures that will remain effective for 10,000 years (in the case of Yucca Mountain, the legislative requirement was 1,000,000 years). This timeline extends far beyond any reasonable expectation for the lifespan of the United States, making waste management essentially un-plannable. As one former Washington Department of Ecology manager told me, "the 10,000 year metric is hubris. It's outside of human beings' capacity to evaluate. We're just pretending, it's just foolishness. But we do it together. I mean there's a whole regulatory system around it."[11]

I heard this and similar sentiments many times while doing research for this dissertation. In fact, as part of my fieldwork, I made a point of asking people I interviewed if they thought the

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[9] After approximately 160,000 years of radioactive decay, 99% of Cold War plutonium will become the stable isotope lead (Pb) For 100% of the radioactivity to have decayed away, it will take 240,000 years (Freer 2011).

[10] Superfund is a federal program administered by the Environmental Protection Agency designed to assess and remediate abandoned hazardous waste sites in the United States. Established in 1980 by the Comprehensive Environmental Response and Liability Act, the program enables the EPA to facilitate cleanup at these sites—either by engaging in remediation activities directly or by compelling responsible parties to perform the necessary cleanup actions. At Hanford, the EPA works with the U.S. Department of Energy (the responsible party) and the Washington Department of Ecology to design and fulfill cleanup requirements through the Tri-Party Agreement.

[11] Personal Interview. Olympia, Washington. February 21, 2012.

Hanford cleanup was possible. The vast majority said no. This is striking, especially considering that most of these individuals were both explicitly pro-nuclear and actively involved in the daily operations of remediation. The following statements provide a useful illustration on this point. When I asked if Hanford could be remediated, these workers told me,

- Progress is possible, but to get all of the way done? No.[12]

- No. Never. There will always be contamination here, it will never be cleaned up. Nobody likes to say this out loud, but it is contaminated forever…There's no place else to take it, no place to put it. They will guard it, hopefully, and guard it well. And I'm not depressed by that because there are still people, and there will still be people who care about the environment to do the best we can. But I don't think we can ever get all of the contamination out of there. I don't think we can. I don't think it's possible.[13]

- A lot of the conversations we have are not operating in reality. We need to figure out a realistic but not bad solution. We need to be willing to talk about how impossible some of the projects are.[14]

- There's no quick fix, there really isn't. There's no quick and easy fix to any of this stuff. And it's just flat not going to happen. As much as I hate to say it, I mean, Hanford's still going to be around probably trying to pump out waste, when my boys have kids and their kids have kids. I hate to say it, but it's true.[15]

What does it mean to engage in an impossible, yet urgently necessary, nuclear cleanup? Like weapons manufacture, the "second half" of the nuclear production cycle is an expensive undertaking. Each year, about 60% of the Department of Energy's budget goes to managing and maintaining the weapons complex. In 2014, for example, the DOE spent $17.9 billion dollars (63% of its annual budget) on weapons-related activities (Image 8). The Hanford cleanup received $2.13 billion of this total.

As the following pie chart demonstrates, nuclear weapons dominate the nation's energy landscape both financially and administratively. Indeed, the DOE spends more than double on nuclear remediation (through the office of Environmental Management) than it does on energy efficiency and renewable energy projects combined. This means that the U.S. government's capacity to develop and implement climate change initiatives or to design innovative energy technologies, is directly proportional to the state of its weapons stockpile and wastes.[16]

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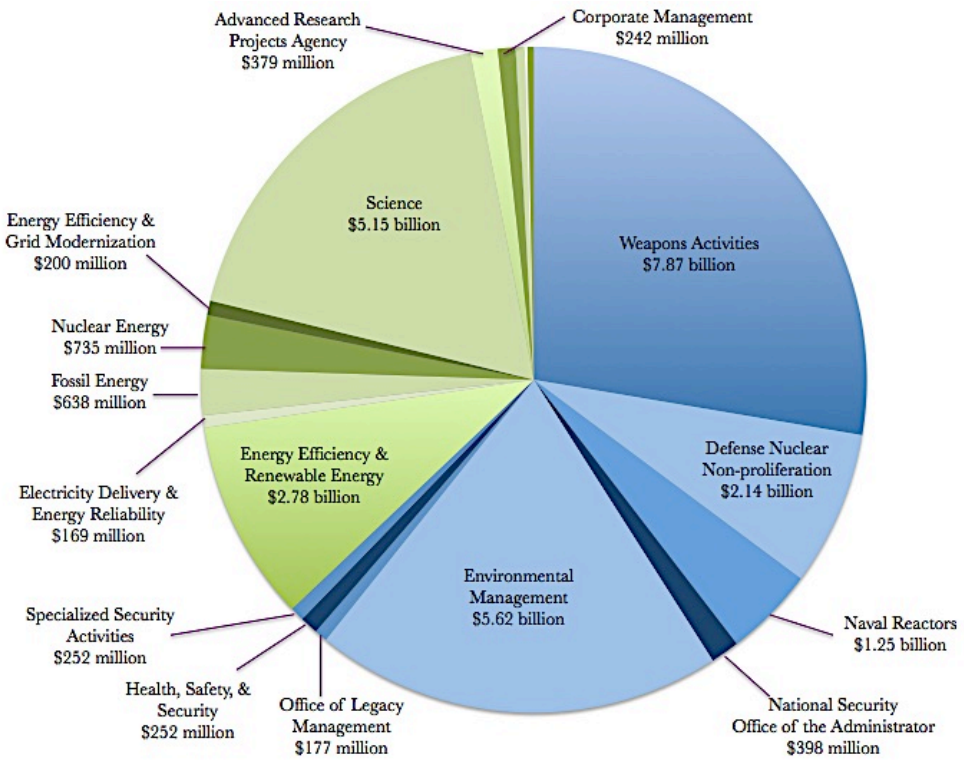
[12] Personal Interview. Richland, Washington. April 12, 2012.
[13] Personal Interview. Richland, Washington. March 5, 2012.
[14] Personal Interview. Richland, Washington. March 6, 2012.
[15] Personal Interview. Benton County, Washington. April 17, 2012.
[16] The impact of nuclear weapons management within the broader DOE administration hit home for me when I spoke with congressional representatives and DOE managers in Washington D.C. as part of my dissertation fieldwork. Each expressed frustration at the strain that nuclear cleanup spending puts on DOE budgets, especially in the face of other pressing environmental concerns. At Hanford, my interviewees told me that fear that the DOE will cut funding makes it even more urgent to show progress and to prove that cleanup is a worthwhile (and possible) endeavor.



8. Department of Energy Congressional Budget Request for 2014. The blue portion of the chart indicates weapons-related spending while the green portion represents non-weapons spending (DOE 2013).

However, despite these large financial investments, many argue that nuclear remediation at places like Hanford has not produced significant results. As the non-profit organization Hanford Challenge argues, "less than 2% of the radioactivity at Hanford has been immobilized, and cleanup operations have only grown in cost and delay. Meanwhile, groundwater plumes of uranium, tritium, strontium-90, and various chemicals flow into the Columbia on an increasing basis" (2015). This begs the question: if not remediation, then what is the Hanford cleanup actually producing?

In this dissertation, I examine the complex and often contradictory politics of nuclear remediation at Hanford. Informed by eighteen months of ethnographic fieldwork and more than 100 in-depth interviews with Hanford workers, managers, activists, and area residents, I explore how nuclear remediation is made "possible" despite its inherent uncertainties. Through four empirical chapters, I make the case that nuclear waste is not socially inert, but distinctly productive. Just as above-ground weapons testing produced the official script for American nuclear disaster with its televised detonations and duck-and-cover drills, I argue that the contemporary spectacle of remediation works to re-define the terms of nuclear citizenship and national security in the face of the nation's enduring waste. Thus, cleanup projects at former weapons sites like Hanford articulate a new social contract for nuclear threat in the post-Cold

War era—one that defines the conditions of "livable" exposure and "acceptable" contamination, highlighting particular hazards while rendering others invisible.[17]

The following chapters examine these social and material processes in different yet entangled ways. In the first chapter, I consider how remediation is made possible through a particular imagination of the body—a statistically calculated human template that I call Jane. Designed to enable explicit statements of risk that could inform radiation protection standards, this composite figure materialized in step with a rapidly expanding nuclear industry. In my analysis, I examine both Jane's genealogy and the consequences of her implementation in remediation practice. Chapter two investigates how the radiation protection standard became an organizing principle for life in the atomic age. Thinking through "permissible exposure" as a biopolitical project, I discuss the disciplinary politics of radioactive fallout and nuclear safety. I consider how American citizens learned to live with exposure, and how atomic risk became a "reasonable" part of modern life and work. In chapter three, I consider how both injury and compensation are integral to the broader social logic of nuclear remediation. Drawing from in-depth interviews with Hanford workers, I discuss the embodied practice of "dose" and the uncertain health effects of radiogenic exposure. Finally, in chapter four, I explore how certain understandings of the environment facilitate nuclear cleanup. Examining the dual production of nature as both untouched wilderness and biological vector, I consider how this slippage between pure and polluted, wild and controlled, has been employed in the service of remediation.

METHODS

This dissertation uses an ethnographic approach, based primarily in participant observation and in-depth interviews. It examines the quotidian, lived spaces of remediation and recognizes individual bodies, bureaucratic standards, and radionuclides as mutually constitutive parts of a greater nuclear industrial whole. Doing ethnographic research within the nuclear industrial complex comes with a set of practical challenges. First, because of the hazardous and often classified nature of nuclear work (and the fact that I am not a formally trained nuclear worker), I could not simply walk onto the Hanford site and spend time with people there. Furthermore, though I have toured the Hanford site multiple times, and my access to its more hazardous places increased when I became a member of the Hanford Advisory Board, I felt protective of my body and did not seek out these opportunities as much as I could have.

Instead, my ethnographic work took place primarily within two venues. The first was a Hanford worker's advocacy organization, where I volunteered full time during the summer of 2009 and then part time during 2011 and 2012. Because this organization is very small (just three full time employees), I quickly became an integral part of daily operations. In addition to providing legal

[17] Another important and interrelated point is that remediation provides an avenue for capital accumulation. The daily work of remediation at Hanford, for example, is run by large private contractors like Bechtel International, CH2MHill, and Lockheed Martin, and incentive structures have a direct impact on cleanup activities. As multiple interviewees have told me, these contracts are often based on cleanup deadlines rather than the amount of material that is removed from soil or groundwater. Thus, there is a structural incentive to "complete" cleanup activities quickly often ignoring residual contamination as a result.

assistance for injured workers and whistleblowers, organization staff facilitated exposure support groups and even attended medical appointments with injured workers when requested.

Being part of this organization introduced me to Hanford workers that I otherwise would not have met. I spent time with these individuals in their homes, ate meals with their families, drank beer on their porches, and shared days boating on the Columbia. Because the organization operated on a shoe-string budget, sometimes we even stayed the night with workers when we were visiting from out of town. Getting to know these people not only helped me to understand the daily realities of radiogenic exposure, but it also schooled me in the social relations of nuclear work. I quickly learned about the consequences that Hanford workers face when they raise safety issues or when they seek medical attention after an exposure event. It also introduced me to the complex and power-laden language of impossibility at Hanford—how a worker's injury or a whistleblower's story could exceed the official terms of the possible.

Second, I spent part of each month attending Hanford Advisory Board meetings. The Hanford Advisory Board (HAB) is a multi-stakeholder body that provides policy advice and recommendations to the Department of Energy. Because I became so engaged in board issues during my fieldwork in 2011 and 2012, I was asked to join the HAB. In 2013, I became a formal board member after a series of interviews and a federal appointment process. I continue to represent the community group Citizens for a Clean Eastern Washington and to attend most monthly board meetings.

My voluntary position on the board allowed me to supplement in-depth interviews with an unusual form of ethnography—one that investigates the social workings of bureaucratic process. The Hanford cleanup is imagined and enacted at multiple scales, and policy development is one. As such, debating remediation procedure with members of the board—in both the formal spaces of the meeting room and the informal spaces of coffee breaks and happy hours—has given me a unique perspective on how cleanup is produced both materially and discursively.

In addition to time with the HAB and the worker advocacy organization, I conducted in-depth interviews with other individuals involved in Hanford's cleanup. I visited the environmental restoration and waste management offices of the Yakama Nation (WA), the Confederated Tribes of the Umatilla Indian Reservation (OR), and the Nez Perce Tribe (ID) where I toured lab facilities and had many long conversations about exposure and illness in tribal communities. I met with Hanford managers in their Richland offices, and interviewed retired Hanford scientists at cafes, coffee shops, and the public library. I spent a week in Washington D.C. meeting with congressional representatives and Department of Energy managers about Hanford as part of the Alliance for Nuclear Accountability's annual "D.C. Days." I learned a great deal from each of these interactions.

Finally, this dissertation is also informed by significant archival research. I received a Resident Scholar award from Oregon State University's Special Collections and Archives Research Center, where I spent the summer of 2013 exploring the History of Atomic Energy archive, the Ava Helen and Linus Pauling Papers, and the Hanford Site Forty-Year Environmental Data Collection archive. So too, my analysis benefits from a critical engagement with the Ernest O. Lawrence papers at U.C. Berkeley's Bancroft Library. Each of these collections has allowed me deeper understanding about the historic conditions that inform Hanford's contemporary politics.

CHAPTER ONE

BECOMING JANE: THE MAKING AND UNMAKING OF HANFORD'S NUCLEAR BODY

I succeeded in discovering the cause of generation and life; nay, more, I became myself capable of bestowing animation upon lifeless matter.

—Dr. Frankenstein

BIOGRAPHY

Jane rises at 6:00 am, after an exact 8.00 hours of sleep. With the practiced ease of repetition, she stretches, yawns, and walks to the bathroom in the soft morning darkness. Stepping onto the bathroom scale, she watches its digital screen blink once, then twice, radiating dim green light around her ankles. After the third blink, it registers her weight—70.00 kilograms—just as it has every morning of her adult life. She nods with satisfaction.

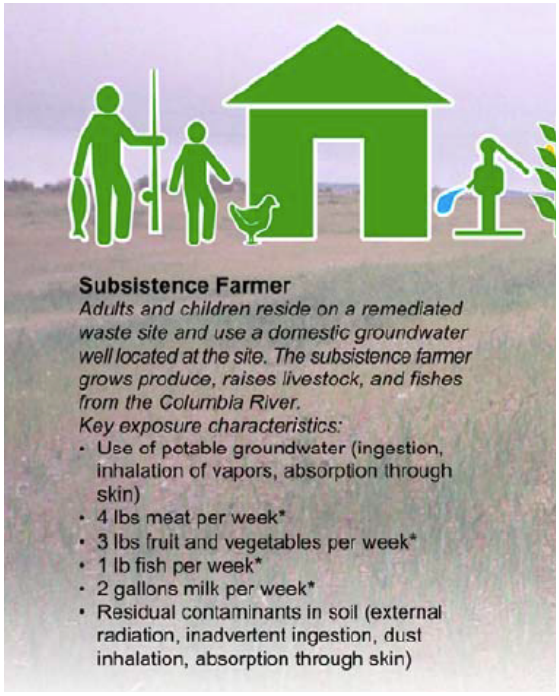
A disciple of numbers, Jane measures and calculates her every action with devoted precision. When working outside, she makes sure that no more than 5,700 cm^2 of her skin is exposed to area soils and she maintains a breath rate of 0.63 m^3/hour as she moves. Her caloric intake is equally deliberate, calibrated in weekly intervals. She consumes exactly four pounds of meat, fourteen eggs, one pound of fish, two gallons of milk, and three pounds of fruits and vegetables every seven days. Each night she takes a bath, making certain that 18,000 cm^2 of her skin is submerged for precisely 34.8 minutes. Then she retires to bed at 10:00 pm and is immediately asleep.

Jane is a member of a community that lives within the pages of the U.S. Department of Energy's *Human Health Risk Assessment* for the Hanford Nuclear Reservation (2010). She is part of a subpopulation of future humans that make their living as subsistence farmers on remediated nuclear industrial land (Image 9). Though currently residing on paper, she plans to engage in on the ground activities immediately following the successful remediation of the Hanford Site. Once settled, she and other exact copies of herself will abide by federally-approved practices for ensuring human health and safety—regulating their breath, sleep, eating, drinking, bathing, and ultimately, their exposure—for the next ten thousand years.[18]

The Comprehensive Environmental Response, Compensation, and Liability Act (more commonly known as the Superfund Act), requires that the Department of Energy design and implement protective measures at Hanford that will prevent excessive threat to human health and the environment for the next ten thousand years (EPA 1985). Thus, Hanford managers and

[18] The figure who I have called "Jane" in this chapter is simply called "Subsistence Farmer" in the DOE's *Human Health Risk Assessment.* Subsistence Farmer (Jane) is one of eight statistically-calculated human types competing for future use rights at Hanford. She is joined by Avid Angler, Avid Hunter, Casual User, Non-residential Tribal member, Industrial Commercial Worker, Resident Monument Worker, and Native American Resident (DOE, 2010).

policy makers must consider administrative eternity, creating cleanup actions and land-use regulations that extend beyond the lifetime of the nation.



9. "Local Resident Exposure Scenarios" (DOE 2010).

Jane is one of many productive fictions critical to the remediation process.[19] Her capacity to exist within the carefully measured bounds of nuclear daily life—and to instill her quotidian practice in future generations—is central to the Hanford cleanup's success. It is important to note here that according to Superfund legislation, "clean" does not necessarily mean un-contaminated. Rather, nuclear industrial landscapes are considered officially remediated once the probability that a human will develop cancer from exposure to residual contamination is 1 in 10,000 (EPA 1985). The challenge of remediation, then, is to measure and manage the conditions of carcinogenic encounter, titrating environmental contamination with human activity to achieve the appropriate balance of "permissible dose" (EPA 1989). Thus, a "successful" cleanup is one that both contains nuclear waste and fashions subjects that can inhabit remediated space, producing an intricate co-constitution of body and environment that complies with the legislative terms of a post-nuclear future.

In this chapter, I consider how Jane has become a figure through which this particular future manifests. I do this by first tracing a brief genealogy of what I call the *nuclear body*—a mathematical translation of flesh and function critical to nuclear industrial practice. Beginning

[19] By providing an official vision of controlled risk in post-nuclear life, Jane represents a version of what Lee Clarke calls "fantasy documents," rhetorical instruments that manage catastrophic potentialities through bureaucratic ritual rather than material action (1999).

with U.S. led studies of radiogenic injury in the aftermath of the Hiroshima and Nagasaki bombings, I consider how exposed Japanese bodies became the primary data source for contemporary nuclear science and regulation. Next, I examine the invention and application of Reference Man—a "universal" human designed to standardize radiation dose calculations across multiple populations. Finally, I return my attention to Jane's implementation in remediation practice at Hanford. Specifically, I discuss the efforts of two local Native American tribes to craft their own future human template, a standardized indigenous body designed for use in Hanford's remediation planning. Rejected by federal regulators as "not physiologically possible," the indigenous body is framed as Jane's constitutive outside, remediation's unthinkable and unrecognizable subject. As such, I consider how cleanup efforts seek to reconstitute life itself—formalizing a new baseline from which to evaluate the boundaries and biologies of post-nuclear existence.

BUILDING THE NUCLEAR BODY

I use the term *nuclear body* to identify a statistically-calculated human template that emerged in the early years of the Cold War. Designed to enable explicit statements of risk that could inform radiation protection standards, this composite figure materialized in step with a rapidly expanding nuclear industry and its associated field of radiation health science. The nuclear body represents a "historical ontology" (Hacking 2004) of permissible exposure, a set of conditions in which nuclear contamination could be recognized as livable.

Radiogenic impact has been studied for multiple generations in a wide variety of populations. Notable examples include Marshall Islanders and American soldiers blanketed by fallout from above ground nuclear tests (Barker 2007; Hansen and Schriner 2005), as well as hundreds of thousands of nuclear workers exposed on the job (Manusco and Stewart et. al. 1977; Cardis and Vrijheid et. al. 2005). These individuals are joined by countless others, both human and non-human (Welsome 2000; Johnston 2007; Brown 2013). From a policy perspective, however, the most significant analysis of radiogenic injury is the Atomic Bomb Survivor Study—a multi-decadal examination of Hiroshima and Nagasaki victims. Now in its sixty-seventh year and renamed the Life Span Study (LSS), atomic bomb survivors along with their children and grandchildren still provide the basic raw data for federal estimates of radiogenic risk in nuclear production, remediation, and worker compensation claims (Krupar 2013; Richardson and Wing et. al. 2013). Because of the centrality of this study in determining American radiation protection standards,[20] I begin my critical genealogy of the nuclear body in the streets of wartime Japan.

The four square miles surrounding the epicenter of the Hiroshima bombing is known as the "zone of complete destruction" (Orient 1988). Though this phrase is most often used to describe

[20] The U.S. Environmental Protection Agency, for example, considers the Life Span Study to be the "most important source of epidemiological data on radiogenic cancer" (1993: 146) and uses LSS data to develop detailed mathematical models for estimating risk (2011). In addition, the National Academies' seminal reports on the Biologic Effects of Ionizing Radiation (BEIR) use Japanese atomic bomb survivors as "the primary source of data for estimating risks of most solid cancers and leukemia" (2006: 2). This data set also informs the U.S. Federal Guidance Reports for exposure to radionuclides that direct nuclear remediation efforts (EPA 1993; EPA 1994).

the spatial extent of structural wreckage, "complete destruction" also evokes the new categories of ruination that were born with the bomb's blast. The massive explosion that ripped through city streets on that hot August morning represented a moment of total rupture, a material and psychological fracturing of what had formerly been understood as reality. Survivors struggled to describe their experience, often finding no words that could capture the unthinkability of the bomb's impact. As Dr. Michihiko Hachiya wrote in *Hiroshima Diary*, "I had to revise my meaning of the word destruction or choose some other word to describe what I saw. Devastation may be a better word, but really, I know of no word or words to describe the view" (1955: 65).

Other survivor testimonies relate the surrealism of complete destruction in small bursts of crystallized memory: the shadow of a vaporized body imprinted on a wall, a bird hopping down the street without wings, scores of charred bodies walking with arms outstretched like so many zombies (Dower 1996; Minear 1990). According to Robert Lifton, atomic detonation produced "an atmosphere so permeated by bizarre evidence of death as to make whatever life remained seem unrelated to a 'natural order' and more part of a 'supernatural' or 'unnatural' one" (1968: 29). This startling inversion of life and death, he argues, created "a psychic closing-off"—a pronounced severing between body and identity, a fundamental reworking of what it meant to be human. Hiroshima survivor Wakashi Shigetoshi wrote that though he found himself surrounded by scenes of incredible suffering following the bomb's impact, the dead and dying "no longer moved me in the slightest. At that time human beings on the point of death were no longer human: they became mere substance. And the man watching them lost his humanity, and also became but a substance" (Takayama 2000: 63).

The *hibakusha*[21] that survived the bomb's blast were deeply impacted both physically and emotionally by their experiences. However, their encounter with atomic catastrophe and their subsequent categorization as "the exposed ones" produced an additional layer of collective transformation: it turned the *hibakusha* into the largest collection of experimental human subjects known to radiation science. The Atomic Bomb Casualty Commission (ABCC), an American organization investigating radiogenic impact in Hiroshima and Nagasaki, saw the *hibakusha* as "a scarce and precious intellectual resource" (Lindee 1994: 4), a group of individuals that ABCC director Robert Holmes called, "the most important people living" (ibid: 5).

Though the original engineers of the Atomic Bomb Survivor Study (ABSS) extolled the unique value of their study population, they acknowledged that drawing concrete conclusions from study data presented several fundamental challenges. First, and most troubling, was the near impossible task of identifying the exact amount of radiation that each survivor received from the bomb's blast. This was especially problematic because a central function of the ABSS was to determine the precise level at which radiation exposure caused biological and genetic harm in humans. Without knowing the dose that each study subject received, the connection between exposure and injury could not be made with any certainty. Thus, ABSS researchers found themselves charged with quantifying the unknown, with making the ambiguous concrete.

In the thousands of interviews they conducted, the ABSS team asked survivors to relive the moment of the explosion, to recall the exact position of their bodies in relationship to walls or

[21] *Hibakusha* is a Japanese word that identifies atomic victims—roughly translated as "survivor" or "exposed one."

rooftops that could have provided potential shielding from the blast and its associated radiation. Survivors were expected to remember in detail their activities immediately following the explosion and to identify the radioactive materials that they could have ingested as they struggled to find family members, water, and shelter. In effect, researchers were asking the *hibakusha* to reconstruct the rubble of Hiroshima and Nagasaki in their minds, to retrieve humanity from the "mere substance" that the bomb had made of bodies—and to translate moments of fractured reality for which no words existed, into exact descriptions that could be used for statistical analysis.

In addition to fundamental uncertainties in dosimetry, the Atomic Bomb Casualty Commission faced other significant barriers to effective data collection. First, the initial years of the ABSS were conducted during the American occupation of Japan, intensifying an already problematic power dynamic between American researchers and Japanese study subjects. Second, identifying who should count as a survivor proved difficult, as the chaos of the bomb upended standard forms of record keeping in Japanese hospitals, police stations, and city government. Unless a victim remained in hospital for many months, survivor records were based almost entirely on voluntary self-identification by the victims themselves. As Susan Lindee writes in *Suffering Made Real: American Science and the Survivors of Hiroshima*,

> Many survivors had substantive reasons for keeping their experiences to themselves. There was a stigma associated with having been exposed to the bomb's radiation. Many believed that survivors would be unable to have healthy children due to radiation-induced heritable mutations, and in a social world where marriages were commonly arranged, some families concealed exposure in an effort to secure desirable matches for their children. In addition, until 1957, survivors qualified for no special assistance or medical care and therefore had little incentive to come forward and register (1994: 8).

Furthermore, while it was possible for epidemiology to make connections between exposure and illness in certain cases, the more subtle, long-term impacts of radiation such as genetic mutation were nearly impossible to detect (GAO 2000). Authors of the ABCC's genetic study warned that because the majority of radiation-induced mutations were likely recessive, they would not become evident for multiple generations—and even then, it would be hard to distinguish radiation-induced mutation from "naturally occurring" mutation. In their initial report on the bomb's genetic impact, study authors cautioned, "it is important to emphasize that the condition of these initial observations…permit the detection of only a small fraction of the total genetic effect of exposure to an atomic bomb. Given our estimates of the radiation dosages involved, it has…always been doubtful whether significant findings attributable to the genetic effects of irradiation would be apparent" (Neel and Schull 1953: 541). Renowned geneticist Herbert Muller offered similar disclaimers about the study's explanatory power, saying, "since the numerous disabilities and deaths occasioned by the [radiation]-induced mutations will be spread out very thinly over a large number of generations, the overall cost, although great, will be much too scattered and insidious to affect the population as a whole noticeably…individual sufferers will be unable to trace their troubles to the source" (1955: 838).

Dr. James Neel, the director of the ABSS genetics program, worried that the study's inability to identify significant genetic impact would unduly influence the risk metrics that informed

radiation protection standards. In his final report for the National Academy of Sciences and the National Research Council, Neel wrote,

> It may be argued [that] the urgency of the problem of setting 'permissible' individual radiation doses is such that we must be guided by the data at hand. There is no doubt concerning the urgency of the problem. There *is* doubt concerning the advisability of calculations which have the appearance of mathematical exactitude to persons not thoroughly indoctrinated in genetics and unfamiliar in the shaky basis of the primary assumptions (1956: 217, original italics).

Ultimately, Neel's fears were substantiated. Despite its inherent uncertainties, the ABSS genetics study was cited repeatedly in policy documents and the popular press as "proof" that atomic materials presented little or no long-term hazard to future generations. Exposed Japanese bodies, reincarnated as bodies of data, were thus used to justify nuclear industrial expansion—to recommend investment in peaceful uses of the atom and to calm fears about above ground nuclear testing. As such, atomic boosters and policy makers were able to make something out of "nothing," using an absence of information to produce truth claims about the relative hazard of atomic living. Uncertainty became a management tool in and of itself, a means for generating political and economic value. In effect, the visible invisibilities of the ABSS data were its greatest gift to nuclear industry.

As both peaceful and military applications of nuclear technology expanded in the early years of the Cold War, the U.S. government was under increasing pressure to calculate industry standards for permissible dose. Thus, while radiation's physical impact was being analyzed in Hiroshima and Nagasaki, scientists also set about determining a standardized body that could be used to estimate harm in broader populations. In 1949, the International Commission on Radiation Protection (ICRP) created what it called "Standard Man" (later renamed Reference Man)—an individual that it believed could represent a basic "set of biological parameters" for risk calculation (1975: 1). Though Japanese bodies produced the majority of raw data about radiogenic injury, Reference Man became the official body through which such information could be applied and understood. With his consistency of form, Reference Man was meant to facilitate discussions among the wider scientific community and to allow for greater ease in quantifying and formalizing radiation's effects.

Though some of Reference Man's biological and physiological parameters have been modified in the decades since his birth, he has retained his general form and fitness for the last sixty-six years. He continues to be, in the words of the ICRP, "20-30 years of age, weighing 70 kg, is 170 cm in height, and lives in a climate with an average temperature of from 10° to 20° C. He is a Caucasian and is a Western European or North American in habit and custom" (ibid: 4). Of course, the ICRP acknowledges that "young western white male" does not adequately describe large sections of the world's population. For this reason, the Committee cautions that Reference Man should not be qualified as "an average or median individual." Rather, he should serve as the internationally agreed upon starting point for estimating radiogenic risk. Radiation scientists and practitioners should use Reference Man as the basis from which further adjustments can be made to suit individual situations, as appropriate. As the Committee states,

> The fact that Reference Man is not closely related to an existing population is not believed to be of any great importance. If one did have Reference Man defined precisely as having for each attribute the median value of a precisely defined age group in a precisely limited locality (e.g. males 18-20 years of age in Paris, France, on June 1, 1964), these median values may be expected to change somewhat with time, and in a few years may no longer be the median values for the specified population. Moreover, the Reference Man so defined would not have this relation to any other population group unless by coincidence. To meet the needs for which Reference Man is defined, this precise statistical relationship to a particular population is not necessary. Only a very few individuals of any population will have characteristics which approximate those of Reference Man, however he is defined. The importance of the Reference Man concept is that his characteristics have been defined rather precisely, and thus if adjustments for individual differences are to be made, there is a known basis for the dose estimation procedure and for the estimation of the adjustment factor needed for a specific type of individual (ibid).

In other words, the ICRP argues that Reference Man's particular race, age, culture, and gender need not preclude him from estimating exposure in a wide variety of human populations. Health physicists should simply start with the white male as their basic human model and adjust skin color, dietary preferences, and/or reproductive organs accordingly. Like Adam in an atomic Eden, the ICRP positions Reference Man as the basic building blocks for a nuclear humanity. Reference Woman, for example, need but emerge from his carefully calculated rib.

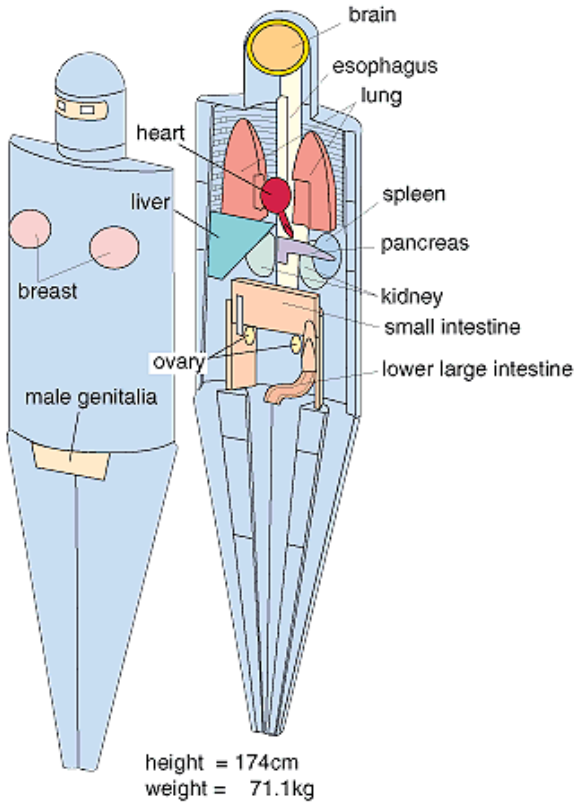
However, managing the "uncertainties" of diversity through real-time adjustments in the Reference Man model presents several obvious problems. First, it fails to acknowledge the obduracy of the regulatory structures in which Reference Man is applied. Radiation protection standards are not supple, self-reflexive beings—their very point of existence is to draw lines in the sand, to enforce a singular and universal notion of permissible dose. The physical infrastructure of nuclear industry is similarly intractable. Nuclear reactors, for example, must be designed according to specific metrics for permissible exposure. They cannot be continually demolished and rebuilt to account for biomedical discoveries or changes in worker population.

Therefore, calculating for diversity in nuclear regulatory standards has meant finding a singular body that can adequately account for collective variety. Many policy documents acknowledge, however, that it would be inappropriate to use only the male body to estimate radiogenic risk, when women are 37.5% more likely to develop fatal cancer from the same level of exposure (NAS 2006). Rather than simply adopting a standardized female body as the basis for risk calculation, however, policy makers engage in what they consider a suitable compromise: they simply give Reference Man breasts, ovaries, and a uterus—creating a hermaphroditic human in order to "solve" the problem of radioactive gender inequality.

Indeed, this multi-sexed version of Reference Man informs much of U.S. nuclear remediation policy. For example, the Environmental Protection Agency's current Federal Guidance Reports on internal and external radiation exposure describe their use of a "hermaphrodite…derived from ICRP Reference Man data" (1993: 184). Though the EPA has also used gender-specific models to calculate dose coefficients, its Federal Guidance Reports specify that "most calculations of organ dose from the intake of radionuclides are based on the hermaphroditic [model]" (ibid:

184). So too, the U.S. Department of Energy's *External Dose-Rate Conversion Factors for Calculation of Dose to the Public* describes its "reference individual" as "an adult hermaphrodite" which consists of a male body that has been "modified [to] include ovaries, uterus, breast, and red bone marrow" (1988: 8).

The notion that Reference Man's hermaphroditic transformation equalizes gender inequality in risk calculation ignores the appropriative character of his statistical sex change. More importantly, it denies the material impact of his continued use for real women's bodies. Though the hermaphroditic Reference Man has female reproductive organs, the rest of his body is male. He retains his original height, weight, and physiological parameters. The amount he urinates, the fat content of his body, the percentage of water in his cells—each calculated using data for a male body—remain the same. Indeed, Reference Man even retains his male signifier when in hermaphroditic form. Study authors use phrases like "the uterus in the Adult Male," for example, to describe "his" female components (Cristy and Eckerman 1987) (Image 10).



10. Hermaphroditic Reference Man Model (Yamaguchi 1994).

Rather than troubling fixed categories of sex and gender, Reference Man-as-hermaphrodite reinforces the notion that women are wholly defined by their reproductive organs. Ironically, this reductionist philosophy fixates on certain parts of female biology while ignoring others that also influence risk. Women are, for example, generally lighter weight than men and, "the lighter

the person, the greater the dose from a given amount of external radiation to internal organs…since there is less shielding of these organs by the rest of the body" (Makhijani 2008: 14). In addition, women's bodies are chemically different from men and they generally contain a greater percentage of fat—characteristics that produce a different relationship to contamination and its associated hazard. By adding breasts, ovaries, and a uterus to an otherwise male body, nuclear policy evokes a (limited) biological imagination of female identity to claim that it has calculated for a gendered difference in risk. It uses a language of equality to create what remains an unequal regulatory framework.

By comparison, Reference Man's race receives far less attention than his sex in radiation protection standards. Indeed, the EPA's Federal Guidance Reports do not mention race at all, stating simply that they use a "hypothetical average adult person" with Reference Man's anatomical and physiological characteristics in order to calculate permissible dose (1999: GL-8). This is problematic for a number of reasons, most notably because the health risks associated with nuclear industry are not borne equally by all people, and an average masks this uneven distribution. Furthermore, the causes of racialized differences in health are multiple and complex, the result of social and economic disparity rather than biology (Epstein 2007; Montoya 2011; Bridges 2011). Therefore, policies that rely heavily upon biological parameters in determining risk, ignore and thus reproduce the greater structural inequalities of exposure-related illness.

Of course, it is this simplicity—this abstraction from the lived experience of exposure—that makes the nuclear body politically useful. Nuclear standards must make radiogenic injury generalizable, translating data from diverse and often incomplete sources into explicit statements of cause and effect. Indeed, building the nuclear body has required untangling exposure-related illnesses from the social and spatial relations that give them meaning. It has meant standardizing notions of risk that can travel easily between the disparate spaces of the battlefield, power plant, and remediation site. Finally, it has meant identifying the official boundaries of permissible exposure and acceptable contamination—bureaucratic markers for survival in an increasingly radioactive world. Thus, building the nuclear body has ultimately meant first defining life, and then determining the conditions in which that life should be considered livable.

HANFORD'S IMPOSSIBLE BODIES

In practice, the internal contradictions of a universal human template come quickly into focus. Because it was designed to be applicable in every radioactive environment, the nuclear body itself is profoundly a-spatial. Critical geographic scholarship has long rejected the notion of a placeless body, pointing instead to the co-constitutive relationship between humans and their daily, lived experiences in space (Cresswell 2003; Massey 1994; Nast and Pile 1998). At Hanford, it is easy to see how daily life in a radioactive environment would differ from its statistical assemblage. Indeed, Jane's story at the beginning of this article demonstrates the awkward results of such ground truthing.

This dissonance between data and lived experience is problematic for Native American tribes surrounding the Hanford site. Hanford occupies 586 square miles of territory that was ceded to the Yakama Nation, the Nez Perce Tribe, and the Confederated Tribes of the Umatilla Indian

Reservation (CTUIR) through the Treaty of 1855.[22] This treaty guarantees that tribes may use Hanford lands in perpetuity for hunting, fishing, pasturing horses and cattle, and gathering traditional foods and medicines (Gephart 2003). Though in 1943 the U.S. government restricted tribal use "temporarily" for the war effort, tribes argue that current remediation efforts must restore full access and respect their legal right to use Hanford lands safely.

Fulfilling treaty rights means re-negotiating how nuclear safety is measured and managed in Hanford's cleanup. As Stuart Harris, director of the CTUIR's Department of Science and Engineering argues, "risk assessment as it stands now is woefully inadequate for addressing Native American concerns" (1998: 2). The first and most obvious problem, he explains, is that Hanford's remediation strategy is based on a suburban model. This not only underestimates tribal risk on a practical level by ignoring exposure from activities like wild food harvesting and spiritual ceremonies, but it also renders structural inequalities between the suburbs and the reservation invisible. As Harris points out, "tribal members typically have a larger burden of co-risk factors such as poor nutritional status, loss of natural diet, poorer access to health care, differences in metabolism, and so-on. This means that tribal members might hypothetically not only receive more exposure [than suburban populations] but might also be more sensitive" to that exposure (ibid: 6).

Tribes argue that addressing these structural differences in Hanford's risk framework requires more than changing diet and activity parameters. As Harper and Harding et. al. write, "Traditional lifeways are not simply suburban during the week with camping out or attending powwows on the weekends" (2012: 813). It is not enough to "simply add more fish or some wild food to a suburban scenario" (ibid). So too, risk frameworks that position humans and the environment as distinct and separable units, miss the integration of culture, environment, and body critical to tribal identity and practice. "Our ties to the environment are much more complex and intense than is generally understood," Harris explains. "Because my tribal culture and religion are essentially synonymous with and inseparable from the land, the quality of the sociocultural and eco-cultural landscapes is as important as the quality of individual natural resources" (1998: 3).

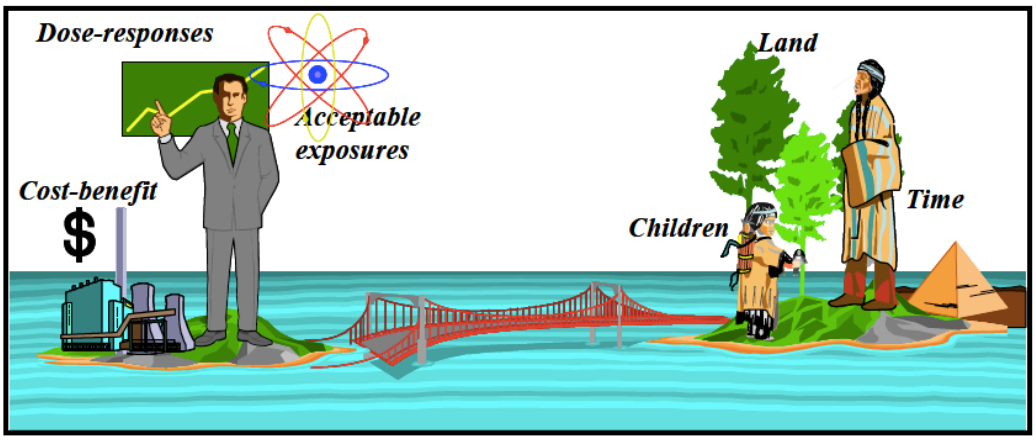
In voicing these concerns, Harris and others are participating in a larger national debate about race, industrial contamination, and the politics of scale. Since its inception, the Superfund program has drawn criticism from environmental and health activists who argue that remediation policies fail to address the raced and classed geographies of exposure. In response to these critiques and a growing attention to environmental justice in the 1990s, the Clinton Administration initiated a series of Superfund reforms intended to "prevent minority and low-income populations from bearing the brunt of pollution" (EPA 2015). At the same time, the EPA faced pressure from regulated industries that claimed that Superfund actions were overly protective and lacked consistent and replicable procedures (Nakamura and Church 2003). Thus, in the same breath, the EPA promised that Superfund reforms would both standardize the remediation process at a national scale and customize it to fit local problems and politics (EPA 1997). The result is a contemporary cleanup policy that requires public participation and local

[22] The Wanapum Band also lived on Hanford lands and maintains strong cultural and material ties to the land. However, because they did not sign the Treaty of 1855, they do not have legal standing in this case.

community input, but that ultimately must translate the particularities of place and person into a set of nationally recognized standards and procedures.[23]

For Hanford area tribes, then, influencing remediation means existing in contradiction. While they argue that statistical models cannot truly capture the web of relations that inform their culture, tribes continue to perform quantitative risk assessments for use in Hanford's remediation planning (Harper and Harris 2010). The Yakama Nation and the CTUIR,[24] for example, have written official exposure scenarios—creating standardized data sets for tribal behavior that can be "systematically validated" within the terms of U.S. law (Harper and Harding et. al. 2008: 231).

Based on a template indigenous person who engages in statistically-calculated traditional activities, tribal exposure scenarios often evoke normative categories of Native American identity. The CTUIR's *Traditional Tribal Subsistence Exposure Scenario and Risk Assessment Guidance Manual*, for example, depicts the difference between indigenous and non-indigenous life using a series of stock cartoon images. One such image, entitled "Bridging Perspectives," presents two cartoon islands connected by a red bridge. On the first island is a white businessman standing beside a miniature nuclear reactor and a large dollar sign. His face is serious as he points to a line graph and the words "cost-benefit" and "dose-responses." The second island holds trees and a Native American elder and child dressed in traditional garb. Clutching a doll in one hand, the child looks over her shoulder, while her elder stares solemnly across the water. Behind them is a miniature Egyptian pyramid with the words "time" and "land" floating above it (Image 11).

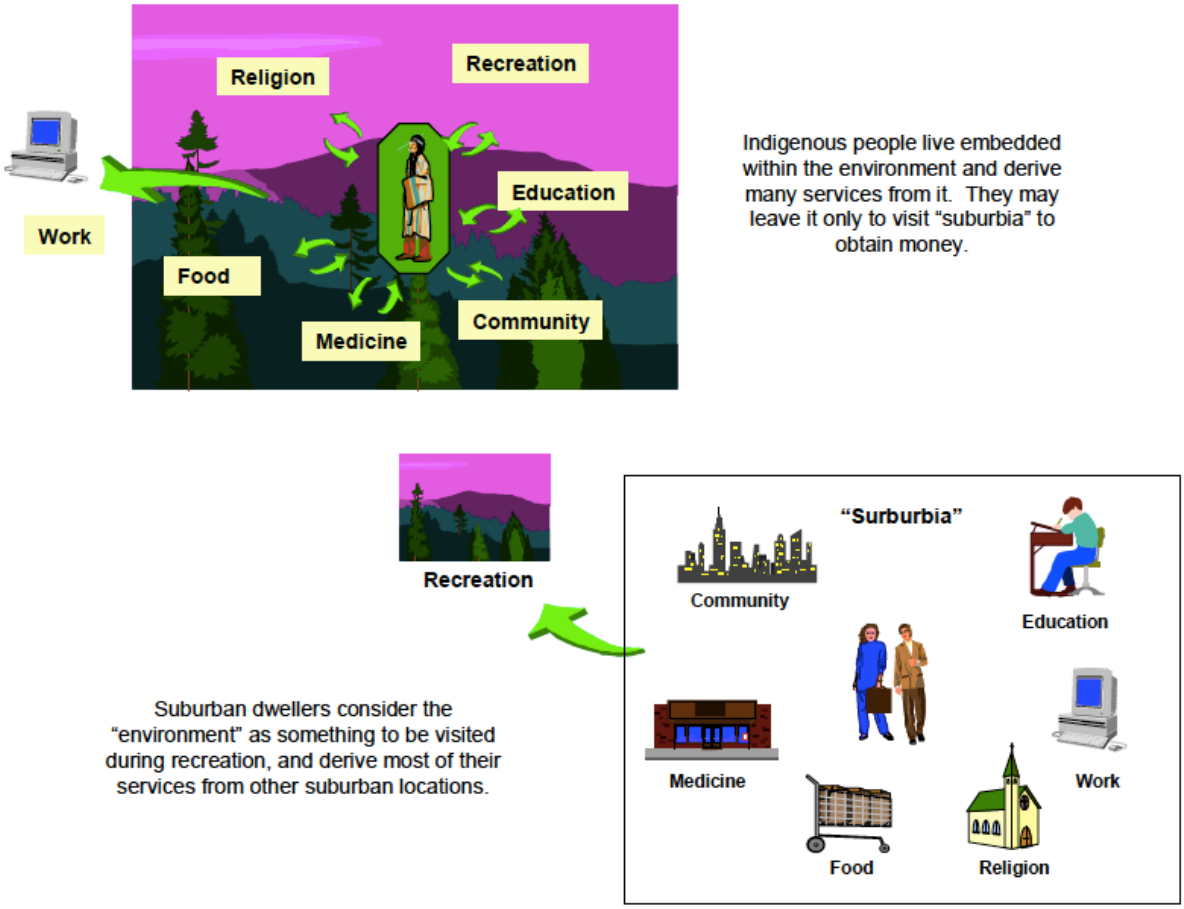


11. "Bridging Perspectives" (Harper and Harding et. al. 2008)

[23] Geographer Ryan Holifield writes that while the Superfund reforms were explicit in their intent to address environmental justice issues, "most were oriented toward preserving the program in a form more palatable to regulated industries" (2012: 594). For example, as part of the reform process, the EPA abandoned its prior default assumption that remediated lands could eventually become residential spaces. Instead, Superfund language now bases is risk assessment and remedy selection on the more ambiguous terms of 'reasonably anticipated future use,' a flexible bureaucratic definition that often implies less stringent cleanup requirements.

[24] The Nez Perce Tribe, which also holds treaty rights to Hanford lands, has not yet created an exposure scenario.

In another example, the same stock image of a Native American has been placed against a backdrop of evergreen trees and purple sky. Surrounded by a series of circular arrows that one might find on a recycling bin, the Native American floats among the treetops as if enchanted. Immediately below, a counter-image labeled "suburbia" depicts a white couple in business attire. Briefcase in hand, the woman cocks her hip to one side while the man looks at her and smiles. Set against a white backdrop, they are encircled by other stock images meant to represent the trappings of suburban life: a computer, a shopping cart, a Christian church, a hospital, a child sitting at a school desk, and a city skyline (Image 12).



12. "Where People Go to Fulfill Elements of their Lifestyles" (Harper and Harding et. al. 2008)

Entitled, "Where People Go to Fulfill Elements of Their Lifestyle," the associated caption reads, "Indigenous people live embedded within the environment and derive many services from it. They may leave it only to visit 'suburbia' to obtain money. Suburban dwellers consider the 'environment' as something to be visited during recreation, and derive most of their services from other suburban locations" (Harper and Harding et. al. 2008: 18). Each image communicates an overt message of difference: different bodies, different practices, different perspectives, and most importantly, different expressions of risk in a nuclear environment. Indeed, in the first image,

Native Americans and non-Native Americans exist on separate islands, indicating a fundamental break.

For the CTUIR, these differences are not only cultural, but temporal as well. Because the Treaty of 1855 describes access to a pre-Hanford landscape, they argue that cleanup should guarantee "*original* lifestyles and resource uses" rather than "*contemporary restricted* or *suppressed"* ones (2008: 27, original italics).[25] As the *Traditional Tribal Subsistence Exposure Scenario* explains, "the intent is to restore the ecology so that the original pattern of resource use is both possible (after resources are restored) and safe (after contamination is removed). This is a different situation than for the general American population, where the intent of remediation is to allow people to continue their *current* (and portable) lifestyle in a newly cleaned location" (ibid: 67, original italics). Therefore, the standardized indigenous body in the CTUIR's exposure scenario represents a past that tribes hope to reclaim: a time before Hanford, before the bomb, before tribal lands and lifeways were "degraded" or "impaired" (ibid: 20). In this sense, the CTUIR are effectively asking that the Hanford cleanup turn back time—retrieving not only chemicals and radionuclides, but a way of life.

In advocating for cleanup levels that recover a pre-Hanford past, the CTUIR simultaneously evoke an oft-criticized narrative that imagines Native Americans as historical subjects, rather than "active parts of the modern world" (TallBear 2013). This and other "strategic essentialisms" (Spivak 1987) in tribal exposure scenarios serve an important political function. As members of a minority population that Superfund reforms promise to protect, tribes argue that Hanford's cleanup should not be considered complete until the level of carcinogenic risk required by law[26] reflects Native American lifeways. Thus, the standardized indigenous body, with its culturally-specific breath rates, soil inhalation factors, fish consumption levels, and so on, invokes the past in order to negotiate Hanford's future. The more risk that tribes can demonstrate in their exposure scenarios, the more contamination that must be removed from Hanford's soil and water table.

However, to communicate the cultural and temporal distinctions that form the heart of their critique, tribes must speak in a standardized language that Superfund legislation can understand. This means that, ironically, tribes must establish statistical and analytical parity in order to make the case for tribal difference. Thus, much time is spent in tribal exposure scenarios positioning the template indigenous person as a legitimate member of Hanford's statistical family—an individual that exists at one end of a spectrum of officially-imagined future humans. As Harper and Harding et. al. argue, "the CTUIR scenario is at the foraging end of the subsistence spectrum, while the residential farmer [Jane's scenario] is at the domesticated end of the subsistence spectrum. Both are active, outdoor lifestyles, and are consistent with the Reasonable Maximum Exposure (RME)[27] approach to baseline risk assessment" (2008: 182).

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[25] By contrast, the Yakama Nation's exposure scenario emphasizes contemporary resource uses and risks to tribal members.

[26] As a reminder, cleanup is considered complete under the terms of Superfund legislation, when no more than 1 in 10,000 people will develop fatal cancer as a result of exposure to residual contamination.

[27] As defined by the Superfund program, a Reasonable Maximum Exposure is, "the highest exposure that is reasonably expected to occur at a site, but that is still within the range of possible exposures" (EPA, 2004: 22).

Official exposure scenarios (both federal and tribal) are thus filled with hundreds of pages of data. In each of these documents, the intimate moments of daily life are given new meaning through statistical translation. In order to evaluate risk from sweat lodge ceremonies, for example, spiritual practice is rendered calculable—mouths and lungs become "exposure routes," bodies become "receptors," and sweat becomes integral to bureaucratic boundary making (DOE 2010: 3-59) (Image 13).

$$I_{inh} = \frac{C \cdot \left(\frac{V_{w-nv}}{\frac{2}{3} \cdot \pi \cdot r^3} \right) \cdot InhR \cdot ET_{sw} \cdot EF_{sw} \cdot ED_{sw}}{BW \cdot AT}$$

13. Formula for Sweat Lodge Exposure (CTUIR 2014).

So too, bodily functions become forms of evidence in disputes surrounding remediation planning. The act of breathing, in particular, has generated significant debate between Hanford area tribes and federal agencies. While the CTUIR argue that the indigenous body inhales 30 cubic meters of air per day (Harris 2011) and the Yakama Nation contends that is 26 cubic meters (Ridolfi 2007), the Department of Energy and Environmental Protection Agency maintain that 20 cubic meters is a more reasonable metric (DOE 2010).

In a series of letters, tribes and agencies negotiate this cultural politics of breath. Defending agency calculations in a 2001 memorandum, the EPA's Marc Stifelman writes, "the default inhalation rate of 20 m^3/day…provides a protective margin and is significantly higher than the long term values recommended in the Handbook."[28] In a 2003 letter, the CTUIR's Stuart Harris responds,

> It is standard practice in risk assessments to include inhalation rates for industrial workers or construction workers (4.8 m^3/hr), using the inhalation rate for heavy activity applied to an 8 hour work day…The memorandum from EPA choosing to apply the suburban rate of 20 m^3/day rather than an active outdoor or industrial/construction rate even though tribal activities more closely approximate the latter, ignores this completely…The value of 30 m^3/day is more scientifically defensible and more accurate for our outdoor lifestyles.

Referencing Superfund reform requirements that tribal populations be consulted throughout the remediation process, Harris continues, "Consultation does not mean informing the tribe what EPA decides or trying to argue the tribe out of its research exposure factors." In a subsequent 2003 letter, he writes in frustration, "[The fact that] I have to spend enormous amounts of time justifying that I live and belong to a unique natural resource based outdoor population seems quite excessive."

[28] Here, Stifelman is referring to the *Exposure Factors Handbook* (2011b), an EPA publication that details human behavior as it relates to contaminated space. The Exposure Factors Handbook provides activity parameters for the nuclear body in Hanford's remediation planning.

Ultimately, these breath rates have provided the rationale for denying broader tribal claims to Hanford's future. As one EPA staff member told me,

> The Yakama and Umatilla[29] have developed their own scenarios, so we run those. Unfortunately, *they aren't physiologically possible*, so we don't choose them. What they did, particularly the Umatilla, is the breathing rate that they chose was from a soldier digging a fox hole, so they were breathing heavy continuously. Which you can't do, and so it makes your numbers go down. So for us, *we can't choose it because it's not credible* (Author Interview 2012).

It is easy to see the irony in this statement. In qualifying the heavily breathing Native American body as not physiologically possible, the EPA ignores the calculative anomalies and uncertainties in its own human template. So too, this statement undermines the notion that Superfund reforms can address the structural inequalities of exposure. For even when tribal scenarios transform complex identities and practices into a singular normative body, that body can only be taken seriously when it does not challenge the official terms of acceptable risk. In other words, once a Native American experiences excessive exposure, he or she becomes impossible. Thus, arguments about indigenous breath are but a proxy for much larger stakes. Hanford area tribes and federal agencies are not only debating lung capacity, they are negotiating the terms of post-nuclear existence—and whose future Hanford's cleanup will make possible.

CONCLUSION: BECOMING JANE

By its very definition, remediation implies full recovery. Descendent of the Latin *remediare*—to heal or cure—it is remedy's grammatical sibling. A noun of action, it is the process of reversing damage and setting right, of mending what has been broken. However, the magnitude of Hanford's contamination and the longevity of its radionuclides make it impossible for remediation to fulfill the promise of its name. Plutonium production at Hanford has created a multi-millennial waste stream that will long outlast the United States and its regulatory policies. Moreover, at a global scale, building and testing atomic weapons has spread contamination worldwide—there is no longer space untouched by the bomb.

How, then, are we to understand Hanford's cleanup? If there is no "after" to nuclear contamination,[30] and no place on Earth beyond its reach, what does it mean to remediate this space? One of this dissertation's central arguments is that a "successful" cleanup at Hanford is one that re-imagines the boundaries and biologies of post-nuclear existence. Remediation is complete once it has made contamination livable by fashioning subjects that can survive in the post-nuclear future. Thus, in identifying who can inhabit remediated space, cleanup re-negotiates the relationship between safety, security, and the contamination it leaves behind.

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[29] The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) are often simply called the "Umatilla" in Hanford discussions.

[30] Hanford's waste challenges human-based concepts of time. Plutonium, for example, has a half life of 24,000 years, meaning it will remain radioactive for 240,000 years. Thus, when I say there is no "after" to nuclear waste, I am referencing human time-scales, rather than geologic ones (Van Wyck 2005).

In *Against Health,* Joseph Masco argues that the social politics of Cold War weapons production have transformed the meaning of health from what was once the "absence of disease" to what is now "a graded spectrum of dangerous effects…embedded in everyday life " (2010: 137). If making the bomb has redefined health and injury, then "unmaking" it through remediation has redefined the associated cure. In each formulation, the slow violence of nuclear contamination is rendered calculable—creating notions of exposure that can move easily between scientific studies and policy documents.

Jane's daily practice in the pages of Hanford's *Human Health Risk Assessment* represents this historically continent sphere of intelligibility. With each breath, her lungs fill with the conditions of possibility for what (and whose) version of life is deemed livable. Thus, in her becoming, Jane embodies a social ontology of nuclear survival. As her calculated body and regulated days inform remediation planning, she remakes the very meaning of trauma and recovery.[31]

The government documents that describe Jane, envision her life in breathtaking detail—her ritual breathing, bathing, and breakfasting, even her penchant for Tae Kwon Do (DOE 2010; EPA 2004, EPA 2011a). Despite their extreme specificity, however, these official accounts are not intended to be read literally. The Department of Energy doesn't actually expect future humans to maintain the same exact body weight each day of their adult lives, nor does it imagine a society of obsessive compulsive individuals that only eat their fruit in fractions. Rather, the numbers that delimit Jane are informed by the laws of statistical error: the notion that mathematical order extends to the very edges of human behavior (Porter 1986). Jane's exposure scenario protects her from the hazards of her post-nuclear environment, because it also sets the terms for what those hazards can be. By living her life in remediated space, then, Jane articulates the conditions of life itself. In effect, she creates the social and environmental order necessary to justify risk-based nuclear remediation.

In this chapter, I have examined several epistemological frames through which we have come to understand nuclear life. I have explored how scientific studies, standards, and social norms have fashioned a nuclear body out of radioactive remains. From the *hibakusha's* indistinguishable genetic mutation and Reference Man's universalized uterus, to Jane's regulated movements and the Native American's "impossible" breath, these framings have conditioned the ways in which radiogenic injury is made visible (and invisible), producing a recognizable subject that defines the very terms of living-being in the atomic age.

Of course, this recognizability is unevenly distributed—some lives are understood as more livable than others (Butler, 2010). Indeed, as I have demonstrated in this chapter, the nuclear body has

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[31] Because Jane negotiates the terms of nuclear risk in her everyday life, and because her daily practice legitimizes state visions of radiogenic recovery on a broad scale, one could argue that she is engaging in what Adriana Petryna has termed "biological citizenship" in the aftermath of the Chernobyl disaster (2002). However, Jane's framing is slightly different. While the exposed Ukrainians in Petryna's account emphasize damaged biologies in order to stake citizenship claims, Jane is not requesting compensation. In fact, according to the statistical and legal logic that made her, Jane has not been injured because her daily exposures have been reconstituted as acceptable. Thus, while she is certainly "producing new kinds of ecologies, bodies, and social orders" (Masco 2006: 301), Jane lends legitimacy to the nuclear state through different means.

been produced through a marked erasure of certain injuries, exposures, and lifeways. Thus, in drawing the bounds of radioactive safety, nuclear science and policy have created a human proxy that cannot truly identify the people it purports to protect. As such, seeking change does not simply mean expanding the nuclear body to include more individuals in its particular embrace, but to consider how the very act of its framing has depended upon distributing recognition and protection unevenly.

CHAPTER TWO

ATOMIC BIOPOLITICS: RISK, REASON, AND THE DISCPLINE OF EXPOSURE

Mr. Parker: *If we accept the principle of acceptable risk in radiation exposure, and there is no alternative today, instead of black and white, we have only infinite gradation of gray from perhaps a black relating to significant over-exposure, grading down but never reaching white. It is beyond our wits to quantify such a scale. Yet the attempt has to be made at least to define bands of gray. The three ranges as used by the Federal Radiation Council, I think, are precisely such an attempt which I have translated into fashionable color terminology with range I being Arcadian gray, range II being Achillean gray, and range III being Augean gray.*

Representative Hosmer: *Do you have a color chart with you?*

Mr. Parker: *I am not able to put precise numbers on these shades of gray but I classify Arcadian gray as pure and clean for the relevant purpose, and Augean gray containing a reference to the well-known stables of history, and the middle range, if I may clarify that, as I recall Achilles, he was pretty sound but he had a couple of weak spots, one on each heel.*

—Herbert Parker, Director of Radiation Protection at Hanford (Statement to Congress, 1962)

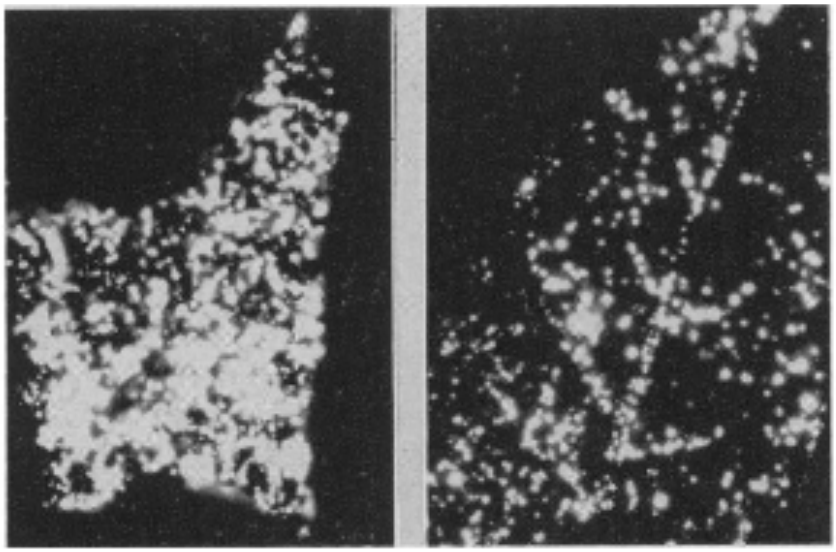
FALLOUT

The evening of April 26, 1953 brought an electrical storm of unusual violence and proportion to the upstate city of Troy, New York. Transforming what had been a warm and sultry day, the storm lashed the city with torrential rains, hail, and high winds. It flooded streets and filled cellars, causing heavy damage to city buildings and infrastructure. According to Chemistry Professor Herbert Clark, of the city's Rensselaer Polytechnic Institute, "it was one of the worst flash storms to hit the area in recent years" (1954: 619). As Clark describes in his 1954 article in *Science*, the extent of the storm's impact was unusual in another respect: it covered upstate New York with "exceptionally high" levels of radioactive material (ibid).

Clark noticed the increased radioactivity mid-morning after the storm, when his radiochemistry students gathered for their Monday lab session. Because classroom Geiger counters were registering high levels of activity, the puzzled professor and his students surveyed a number of locations surrounding the laboratory building. For their effort, they found readings that were greater than "one thousand times higher" than natural background radiation (ibid: 621). A former Manhattan Project scientist, Clark suspected that the elevated activity was the result of fallout from above ground nuclear testing, though he was surprised by the quantity of material they encountered. After all, the Nevada Test Site, proving ground for such detonations, was more than 2,300 miles away.

Seizing the opportunity for student learning, Clark directed his class to gather samples from the surrounding area, testing puddles, streets, rooftops, plants, sidewalks, city reservoirs, and water from household taps. In some places they found the extent of contamination so great, that

porous materials like roof shingles and leaves could produce "autoradiographs" (X-rays of themselves) with accumulated radioactive particles (Image 14). Perhaps more disturbing was the discovery that local drinking water registered radioactivity levels 100-1000 times greater than normal. A call to a friend at the Atomic Energy Commission's New York Health and Safety Laboratory confirmed Clark's suspicions as to the source of the radioactivity. Test Simon, part of the Upshot-Knothole series of above ground nuclear tests, had been detonated on April 25, 1953—the day before the storm.

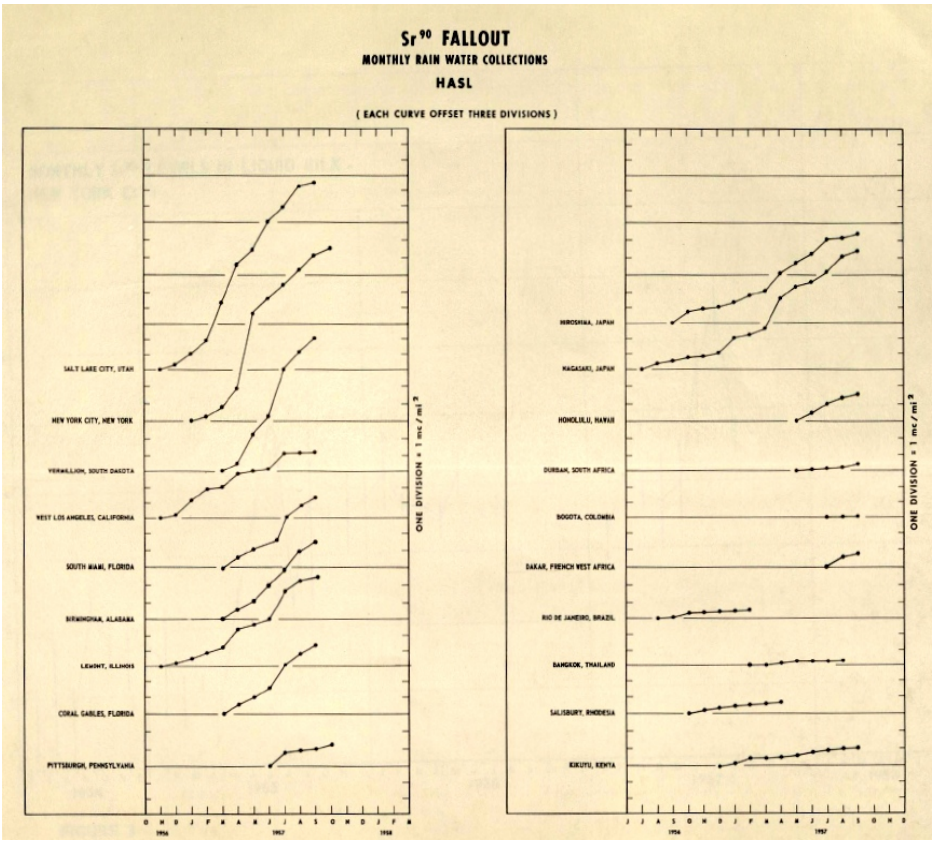


14. Autoradiographs from student sampling efforts. On the left is a piece of asphalt shingle, on the right is a burdock leaf (Clark 1954: 620).

Despite the high levels of activity that Clark and his students identified in city drinking water, the New York State Health Department and the Atomic Energy Commission (AEC) considered possible impact to human health and the environment to be minimal and did not recommend preventative measures like water filtration. Professor Clark echoed their assessment in his article, saying the radioactivity levels they found were high but "not hazardous" (ibid: 619). However, though the Atomic Energy Commission repudiated the health risks associated with radioactive "rainout" in Troy, they could not deny its implications regarding the atmospheric behavior of nuclear materials. Before Clark's discovery, the AEC had confidently maintained that fallout would remain in the stratosphere for years, even decades, after nuclear tests, allowing radioactive material time to decay to safe levels before returning to earth. The blanket of atomic particles that covered Troy a mere *one day* after a nuclear detonation not only undermined this reasoning, but made all other rainstorms of the atomic age suspect as well (Image 15).

Troy became part of a larger conversation about the impact of radioactive fallout worldwide. For the next decade, studies connecting fallout with bodies and environments filled scientific journals, government documents, and the popular press reporting elevated radioactivity readings as far away as the Amazon basin and the high arctic (Palmer 1964; Kulp 1955). Strontium-90, a carcinogenic byproduct of nuclear detonation, sat center stage in these discussions. Because it is

chemically similar to Calcium, Strontium-90 is easily absorbed by bone and blood forming tissue, contaminating not only human and animal bodies but the milk they produce as well. Thus, milk—that superhero of the 1950s food pyramid—became a protagonist in the debate surrounding above ground weapons testing and its impact. Maps of worldwide fallout distribution were often informed by milk and cheese sampling, producing reports that linked detonations directly to global food supply.

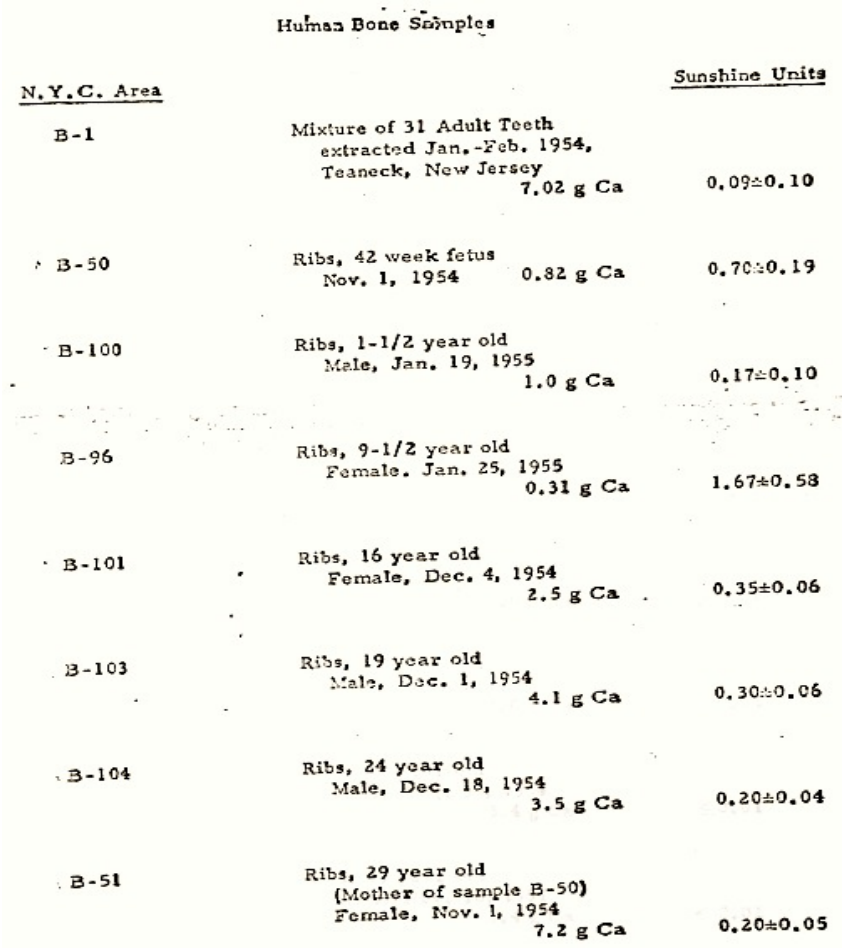


15. Strontium-90 in rainwater worldwide, 1956-1958 (Libby 1958)

In 1953, the Atomic Energy Commission secretly initiated the unfortunately titled "Project Sunshine" in an attempt to officially "define the effect of long range fallout on the human race" (Kulp 1995: 15). Seeking to measure what it called "Sunshine Units"—units of Strontium—the AEC collected almost fifteen thousand human bodies and six hundred human fetuses from countries around the world, often having cadavers flown in from abroad for study.[32] Bones from children and infants were particularly sought after as their faster growing cells produced clearer links between contaminant and country on Strontium distribution maps. These project reports

[32] Bone analysis was considered so essential to analyzing the impact and distribution of fallout, that Willard Libby said in a classified conference meeting, "Human samples are of prime importance. If anybody knows how to do a good job of body snatching, they will really be serving their country" (Welsome 1999: 301).

engage in a particularly surreal form of nuclear accounting—containing lists upon lists of disassociated body parts that have been calibrated in units of sunshine (Image 16).



Human Bone Samples

N.Y.C. Area		Sunshine Units
B-1	Mixture of 31 Adult Teeth extracted Jan.-Feb. 1954, Teaneck, New Jersey 7.02 g Ca	0.09±0.10
B-50	Ribs, 42 week fetus Nov. 1, 1954 0.82 g Ca	0.70±0.19
B-100	Ribs, 1-1/2 year old Male, Jan. 19, 1955 1.0 g Ca	0.17±0.10
B-96	Ribs, 9-1/2 year old Female. Jan. 25, 1955 0.31 g Ca	1.67±0.58
B-101	Ribs, 16 year old Female, Dec. 4, 1954 2.5 g Ca	0.35±0.06
B-103	Ribs, 19 year old Male, Dec. 1, 1954 4.1 g Ca	0.30±0.06
B-104	Ribs, 24 year old Male, Dec. 18, 1954 3.5 g Ca	0.20±0.04
B-51	Ribs, 29 year old (Mother of sample B-50) Female, Nov. 1, 1954 7.2 g Ca	0.20±0.05

16. Sunshine Units in Human Bone Samples (Kulp 1955).

Though the AEC maintained that Project Sunshine found contamination levels that were still "less than the theoretical maximum permissible concentration" allowed by federal standards (cite), confidential annual reports for the project were shot through with an underlying sense of foreboding. As project director J. Laurence Kulp wrote in 1955,

> Based on the observed concentrations of Strontium-90 in human bone, it is clear that the contamination of this isotope has reached a startlingly high level, at least in the highly susceptible young age group…it is obvious that unless either the rate of production and distribution of Strontium-90 onto the earth's surface is appreciably decreased, or an integrated prophylactic program is set up, harmful effects may be forthcoming in future years (64).

Unfortunately, the AEC did not heed its own warnings and instead increased the number and scale of above ground detonations for the next eight years.

Much has been written about the history of nuclear fallout, and it is not my intention to simply replicate those stories here. Rather, I recall this historic moment in order to examine the forms of social governance that emerged as a result of fallout studies and debates. In this chapter, I consider how the radiation protection standard became an organizing principle for life in the atomic age. I explore the daily social production of standardized "permissible exposure" in the laboratory, the halls of congress, the 1950s kitchen, and the nuclear reactor. So too, I pay attention to the "reason" of permissible exposure in the context of nuclear work, and discuss how liberal ideals of individual choice became integral to the logic of radiation protection. I argue that in learning to live with the ambiguous and unseen hazards of radiation, American citizens came to embody a strategic Cold War calculus: that exposure was an acceptable price to pay for national security.

CONTAMINATED LIFE

Joseph Masco has argued that public renderings of nuclear devastation in the form of above ground weapons testing served as a form of "psychological reprogramming of the U.S. public for life in a nuclear age" (2008: 363). The utility of these spectacular explosions was expressed explicitly in confidential government documents, where weapons tests were described as essential to the citizenry's "emotional adaptation" to nuclear crisis (ibid: 367). Envisioning catastrophe was seen as a critical part of national security, a means of promoting "'psychological defense' aimed at 'feelings' that would unify the nation in the face of apocalyptic every day threat" (ibid). The challenge, Masco argues, was to achieve the right balance between fear and terror. Citizens should be scared enough to ensure constant vigilance against nuclear attack, but not become so overcome by panic as to be incapacitated. The threat of nuclear annihilation had to become normalized, while still retaining its cultural impact as a unifying force in support of Cold War policies and agendas.

Thus, above ground tests like "Operation Cue"—a live televised nuclear detonation over a full-scale replica of a "typical" suburban city, which was viewed by 100 million Americans and narrated by Joan Collins—allowed the U.S. citizenry to practice this appropriate balance between nuclear terror and nuclear fear. Critically, though Operation Cue depicted scenes of sensational destruction, its central message was one of survival. The mannequins that peopled Operation Cue's model city were successfully "rescued" unscathed from the rubble by Emergency Personnel. Some were even flown to area hospitals. Operation Cue told the American people that survival in nuclear war was possible for those who were mentally and emotionally prepared for it. As such, above ground weapons tests "did not resolve the problem of the bomb but, rather, focused citizens on emotional self-discipline through nuclear fear. It asked [the American public] to live on the knife's edge of a psychotic contradiction—an everyday life founded simultaneously in total threat and absolute normality—with the stakes being nothing less than survival itself" (ibid: 376)

I want to extend Masco's argument here to consider the conditions of psychosocial management as they relate to debates surrounding nuclear fallout. I argue that fallout changed the scale and

context of nuclear annihilation by translating the bomb's spectacular and explosive qualities into the silent spaces of the everyday. Because of fallout, Americans weren't simply awaiting the bomb's impact, they were living it—it arrived with the milkman and the weather. The nuclear catastrophe that public discussions of fallout imagined did not exterminate hundreds of thousands of people in one blast, but instead picked them off individually through stillbirths and leukemia, thyroid disorders and mutation. Fallout made the mundane suspect. A child splashing in a puddle, a mother breastfeeding, even the simple act of breathing contained new elements of risk. Thus, the politics of contaminated life—whose new forms of hazard were owed largely to U.S. governmental actions in the name of national security—required additional forms of social and political negotiation.

In 1955, Atomic Energy Commissioner Willard Libby said in a closed-door meeting of the AEC, "People have got to learn to live with the facts of life, and part of the facts of life are fallout" (Kosek 2006: 261). Libby's no-nonsense statement points to the absolute nature of the bomb's impact. Nuclear technology did not simply threaten life, it became a definitive quality of living. Though for Libby, facing the facts meant overcoming increasing public dissent that threatened to end nuclear testing, for individual Americans it truly meant *learning to live* with the "facts" of the bomb. It meant understanding and embodying the official parameters of nuclear safety. Asking, how much milk can a person drink before he or she develops cancer? And, should I let my child play in the rain? Learning to live with the bomb meant both an existential and material reworking of daily practice, building a new understanding of what it meant to survive in the nuclear age.

Because fallout discussions tended to center around food and children, the onus of nuclear safety often fell to women, traditional keepers of the 1950s and 60s home. Caltech professor Linus Pauling, Nobel Laureate and vocal opponent of above ground testing, received many letters from concerned mothers wanting clear directions for ensuring their family's health and security. One letter from a Mrs. Etta Linton, for example, contained an itemized list of precautions that she and her family were taking and wanted to know if Dr. Pauling felt they would suffice. An excerpt from her eleven-point list is as follows:

- The purchase of 150 pounds of locally produced powdered milk. I was assured the milk had been processed before the Soviet tests resumed. No fresh milk purchased since that time, although we are not so rigid we do not allow children to drink fresh milk in other homes from time to time…I also keep a quantity of canned milk on hand.

- The addition of 1 teaspoon daily of dicalcium phosphate to the children's diet. I am still nursing our 13 month old (and do not encourage him to wean himself until he is two as I understand this is his biggest bone-building period).

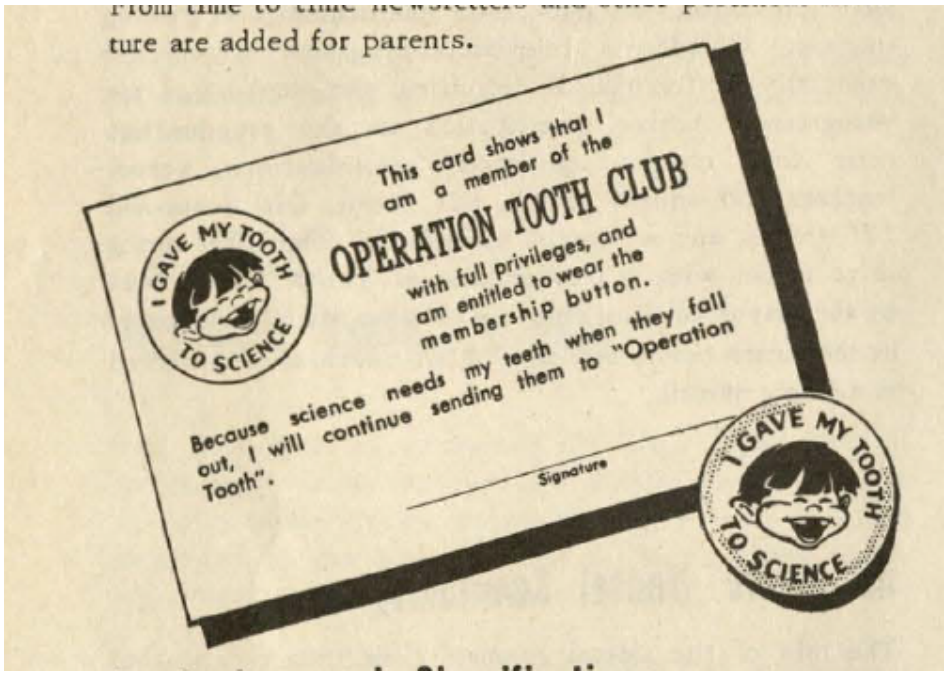
- Sticking to well-aged cheese (the adults in our household prefer it anyway).

- Abandoning the use of wheat-germ (which I had very erratically tossed into meat loaf, etc. from time to time).

- Not making a game of playing in the rain. Discouraging the drinking of rain water. (When we were able to find out what the background radiation was, we tended to keep the children indoors—in our wooden house—where feasible, when the levels were over .03 milliroentgens per hour) (1962).

Almost every letter that Pauling received from these mothers was apologetic, each expressing regret for "pestering" such a famous and no-doubt busy professor, but feeling at a loss as to "where to turn" for information. And indeed, learning to live with the bomb presented several critical challenges. The first, and most basic, was how to interpret the widely conflicting information available about fallout and its potential hazard. Though the Atomic Energy Commission maintained that there was "virtually no danger from radioactive fallout" (even promoting bomb-watching in the desert Southwest as "an entertaining and educational holiday activity" for families and school groups) (Caufield 1989: 106), stories about malformed babies and animals emerging from the Marshall Islands and Nevada Test Site proved damaging to the AEC's credibility.

Independent and citizen-based studies sought to fill informational gaps about fallout, and these alternative interpretations populate the literature of the time as well. One notable example is the "Baby Tooth Survey," a multi-year study conducted by St. Louis based anti-nuclear group the Committee for Nuclear Information (CNI) in cooperation with Washington University's School of Dentistry. Designed to measure Strontium-90 levels in children by analyzing hundreds of thousands of baby teeth, the CNI enlisted school superintendents, teachers, local dentist offices, Boy and Girl Scout troupes, church groups, and television stations to spread the word about the study. Participating children received a button proclaiming, "I Gave My Tooth To Science!" and an official Operation Tooth Club membership card (Image 17).



17. Operation Tooth Club membership card (CNI 1961).

CNI's marketing campaign proved so successful that by 1961 they were receiving over 100 teeth every day (Logan 1964). By 1964, they had collected almost 160,000 teeth and could demonstrate clear links between weapons testing and Strontium-90 in St. Louis area children (CNI 1961). One 1964 analysis of the Baby Tooth Survey data found that Strontium-90 levels in the teeth of bottle-fed infants had risen to over 30 times what they had been in 1951 (Blumenthal 1964). However, despite such striking numbers, the results of the Baby Tooth Survey failed to adequately predict whether or not these children would develop cancer from the measurable contamination in their bodies. They owed this failure to the fact that studies proving the exact level at which Strontium-90 produced cancer in humans simply did not exist. Though the CNI used studies in mice to approximate potential damage, they admitted that "there is no certain way of translating information from animal experiments to the human situation" (ibid: 7).

Instead, seeking clear boundaries for atomic safety that could give their survey official meaning, the CNI was forced to reference their data against federal radiation protection standards. However, even this proved difficult, as Federal Radiation Council guidelines for radiation protection seemed to change depending on the context of each exposure event. As one frustrated CNI representative said before Congress's Joint Committee on Atomic Energy in 1963,

> The U.S. Public Health Service…refer[s] to the Radiation Protection Guide (RPG) as the relevant guide when cumulative yearly dose from a particular isotope appears to be below the RPG…and [refers to] the Federal Radiation Council's statement of September 10, 1962 when the RPG is exceeded. During the critical period in the fall of 1961, for example, the following statement appeared in a U.S. Public Health Service press release: "…It should be emphasized that the quantities of Iodine 131[33] that have accumulated in milk to date do not exceed the Federal Radiation Council guidelines for yearly consumption under normal peacetime conditions…"
>
> When the RPG is exceeded, the September 10, 1962 statement is applicable:
>
> "The Radiation Protection Guidelines are not a dividing line between safety and danger in actual radiation situations, nor are they alone intended to set a limit at which protective action should be taken, or to indicate what kind of action should be taken. As applied to fallout, guides can be used as an indication of when there is a need for detailed evaluation of possible exposure risks and when there is a need to consider whether any protective action should be taken under the relevant circumstances" (CNI 1963: 6).

This ambivalent use of the federal Radiation Protection Guide in determining the impact of nuclear fallout made it difficult for American citizens to understand their relationship to contamination. Making this point clear, the same CNI representative said, "in the absence of standards, public health officials and individual physicians cannot adopt a meaningful policy with respect to countermeasures [against fallout]…Our task of public education and that of similar organizations throughout the nation would be made less complex if the current state of radiation standards were less chaotic" (ibid). As such, he makes the case that standards are a critical

[33] I-131 is another common byproduct of nuclear detonation—like Strontium-90 it was found in human and animal bodies at increasing rates following above ground testing. I-131 accumulates in the thyroid tissue and has known carcinogenic properties.

component in the social construction of nuclear safety—a central organizing principle necessary for teaching Americans how to "learn to live" with the nuclear "facts of life." He argues that clear radiation protection standards for fallout would reduce the chaos and uncertainty of nuclear living by identifying an explicit and enforceable line between safety and danger.

Though they disagreed about the relative hazard of radiation, anti-nuclear groups like the CNI and pro-nuclear organizations like the Atomic Energy Commission agreed that standards would eliminate the social anxiety that accompanied atomic ambiguity. The challenge was where to draw the line between health and illness, between precaution and protection—and ultimately, between the benefit of nuclear technology and its cost. Because fallout had reached the far corners of the globe, few spaces were exempt from nuclear materials. Thus, radiation protection standards were not made to distinguish between the contaminated and the un-contaminated (that distinction no longer existed). Rather, they represented the amount of contamination that was considered livable within the terms of "acceptable" risk.

According to the 1954 U.S. National Bureau of Standards Handbook on *Permissible Dose from External Sources of Ionizing Radiation*, "it is necessary to assume that any practical limit of exposure that may be set up today, will involve some risk of possible harm" (21). Therefore, the Handbook argues that the task of standard-makers is to identify and authorize the particular exposure level at which that risk becomes acceptable. This calculus of acceptability is deeply informed by a Cold War political structure that understands permissible dose in relationship to a nation under threat, where the sacrifice of some is necessary in the interest of securing many. Early dose estimates, for example, calculate the relative strategic advantage of using atomic weaponry on the battlefield and contain estimates for how long American troops could work in a highly radioactive environment before being "rendered ineffective" (Caufield 1989: 67).

So too, America's potential for economic and technological advance in the atomic age becomes a variable in risk calculation. If precautions to ensure worker health and safety cause delay and added expense, standard-makers argue, do they not put the nation at risk by impairing its economy and capacity for innovation? When setting protection standards for nuclear workers, for example, Lauriston Taylor of the National Council on Radiation Protection said,

> I see no alternative but to assume that [an] operation is safe until it is proven to be unsafe. It is recognized that in order to demonstrate an unsafe condition you may have to sacrifice someone. This does not seem fair on the one hand, and yet I see no alternative. You certainly cannot penalize research and industry…by assuming that all installations are unsafe until proven safe. I think that the worker should expect to take his share of the risk involved in such a philosophy (Leopold 2009: 149).

Radiation protection standards thus embody official judgments about the relative value and meaning of life in the nuclear age. Decisions about what makes life livable are entwined with the exigencies of national security and economic efficiency. Therefore, in producing the official terms of nuclear exposure, life becomes an object of state calculation and strategy, a biopolitical enterprise in which *living* becomes a means for securing and standardizing the population (Foucault 2004). So too, standards for radiation protection embody value judgments about the acceptable cost of technological advance and economic expediency. They normalize exposure as an unfortunate, yet inevitable, attribute of modern life.

Critically, in these scenes of biopolitical administration, American citizens are not simply consumers, but also purveyors of the state's notion of "acceptable risk." In order to successfully reprogram its citizenry for life in the nuclear age, the U.S. government had to convince its citizens that radiation protection standards were the lynchpin of nuclear safety. It was not as important that they embrace the particular numbers that the standards represented, for those numbers changed with new scientific studies, political campaigns, and industrial regulations. Rather, the American people had to adopt the radiation protection standard as an organizing principle for life—so that even if the standards changed, the idea that there *should be* standards that performed such relative cost-benefit analyses would not be in question.

Positioning the radiation protection standard as a benchmark for nuclear safety purportedly helped avoid what Lauriston Taylor called a "psychologically dangerous" fear of radiation (Caufield 1989: 137). It also diverted attention from the inevitable genetic impact that would eventually result from nuclear testing. Nobel prize winning geneticist Herman Muller had found in the 1920s that any dose of radiation had the capacity to cause mutation in fruit flies and his findings were cited frequently in fallout discussions. Thus, a critical function of the radiation protection standard was to calm anxieties about fallout's near certain impact in future generations, an impact that could not now be erased. By setting the terms of "acceptable risk," the standard performed the political and statistical acrobatics necessary to reimagine the bomb's impact—making "safe" synonymous with "safe enough."

Psychosocial management was achieved when the use of federal standards for evaluating radiation safety became normalized, when the public accepted the notion that nuclear impact could be captured in a series of mathematical calculations. By reorganizing daily practice according to federal safety standards from the home to the reactor, American citizens performed this new logic of nuclear containment. Reducing milk consumption or eating aged cheese to maintain "safe" levels of fallout in one's diet, for example, actually granted cultural and psychological validity to the notion that there was an acceptable boundary for nuclear contamination. In effect, by adopting the radiation protection standard as a "fact of life," U.S. citizens were manufacturing containment out of the bomb's uncontainable remains.

MAKING EXPOSURE REASONABLE

In late spring of 1960, the U.S. Congress Special Subcommittee on Radiation held seven days of public hearings entitled, "Radiation Protection Criteria and Standards: Their Basis and Use." Focused specifically on the structural administration of nuclear safety, the hearings considered how best to regulate radiation protection through the auspices of government. Under debate was the question of who should develop radiation protection standards and how such criteria should then be applied in on-the-ground "atomic energy activities"[34] (U.S. Congress 1960: 1). Together,

[34]"Atomic energy activities" in this case refer to both nuclear energy and nuclear weapons facilities. However, it is important to note that federal standards for radiation protection are not applied universally across the U.S. nuclear industrial complex. The Nuclear Regulatory Commission (NRC), for example, regulates civilian nuclear energy facilities while the Department of Energy (DOE) regulates nuclear weapons facilities and their associated remediation projects. Meanwhile, the Environmental Protection Agency (EPA) maintains standards for nuclear exposure to the public, and these requirements have at

these seven days of testimony create a narrative picture of radiation protection as it emerged during the Cold War. They provide a window into the official making of nuclear safety, a series of cost-benefit calculations that later crystallize into the current policy of ALARA (As Low As Reasonably Achievable).

With few exceptions, both witnesses and congressional representatives spoke openly about the political and economic necessity of radioactive exposure, at times even framing injury as a measure of social progress. Indeed, the official hearing summary makes it clear that radiation protection is not designed to prevent harm altogether, stating bluntly, "None of this information contemplates absolute protection. Radioactive materials will be released into the environment. Occupational exposures will occur regularly. Accidents will occur" (ibid: 25). Rather, the purpose of the radiation protection standard is to enforce a level of exposure that the "average individual" would be willing to accept (ibid: 58). As the representative from the U.S. Naval Radiological Defense Laboratory testified,

> We cannot insist on…zero risk in the development of new industry which contributes immensely to man's well-being, wealth, and power over his environment. Some degree of biological effect is associated with any exposure to ionizing radiation, and this effect must be accepted as inevitable. Since we don't know that these effects can be completely recovered from, we have to fall back on an arbitrary decision about how much we will put up with; i.e., what is "acceptable" or "permissible"—*not a scientific finding, but an administrative decision* (ibid: 6, italics added).

The point of the hearings, then, was to craft a bureaucratic definition of acceptability and to design frameworks for its implementation across a rapidly growing nuclear industrial complex. In general, speakers agreed that exposure should only be considered "acceptable" when the benefits outweighed the risks. However, translating this general philosophy into a specific numerical value presented significant challenges. As Hanford scientist Jack Healy put it,

> We would like to strike a balance in which the maximum benefits are obtained through use of radiation with the minimum harm. [However], we cannot accurately define the risks nor can we accurately define the benefits to all people. Even if we could define these factors, there would still be controversy as to the proper level at which the balance should be taken…Ultimately, our problem resolves itself into the broad area of overall social risk and progress…How do we strike a proper balance between the interests of the individual and the interests of the Nation?" (ibid: 21-22).

Healy was one of many at the hearings that raised this critical question of scale. At what point do the benefits of collective security outweigh the costs of individual sacrifice? How should the government formalize such a hierarchy of acceptability? Is the loss of one body too many? What about ten thousand?

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times differed from NRC and DOE mandates. Finally, individual states often maintain their own requirements for nuclear safety that may or may not coincide with those of the NRC, DOE, and EPA. This continued lack of interagency consensus produces an uneven and contested geography of permissible exposure across the United States.

As I have argued, these questions were especially urgent in the context of nuclear fallout. Fallout debates positioned prominent scientists like Linus Pauling and Ralph Lapp against the Atomic Energy Commission[35] as each sought to define the appropriate boundaries of nuclear safety. While the AEC envisioned nuclear threat in the form of a Soviet attack, others like Pauling and Lapp emphasized the longer term impacts of nuclear exposure to the general public. Like the 1960 hearings, these debates pointed to critical contradictions between national security and public health. As Mike Wallace asked Lapp in a 1957 interview, "Let's say for the sake of argument, say that we do run the risk of some physical harm from radiation. Now, which do you prefer…do you prefer the kind of risk to your body and that of your children…or the possible risk of moral and spiritual slavery that could result if we stopped the nuclear tests and thus lowered our guard against Russia?" (Wallace 1957).

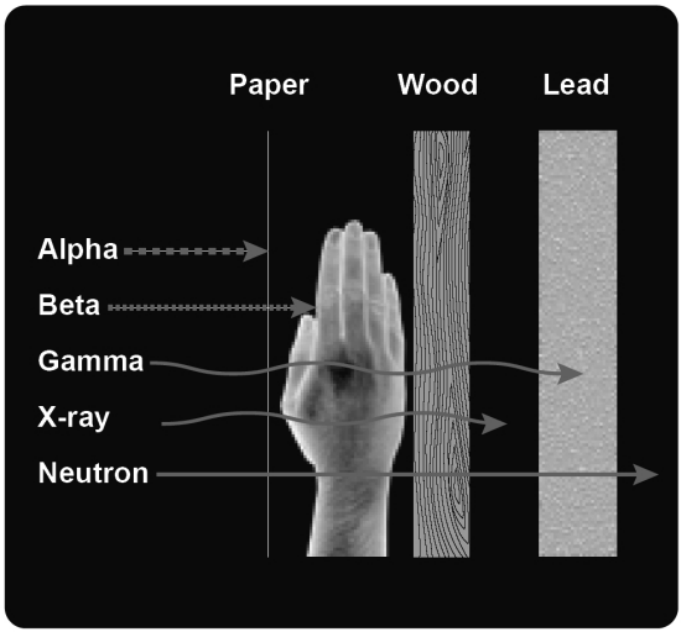
Calculating the official terms of nuclear safety was further complicated by the material realities of radiation itself. To begin with, the human body cannot sense ionizing radiation. It has no sound, smell, or taste, it imparts no pressure to the skin, the naked eye cannot see it. Furthermore, radiogenic injury often takes decades or even generations to manifest, making it difficult to identify exposure as the cause.

The physical act of measuring exposure is also difficult and rife with uncertainty. First, guidelines for radiation protection permit a different level of dose for each part of the body. The skin, hands, forearms, feet, shins, and calves are allowed more exposure than the lenses of the eyes, and still more than the critical organs. Second, there are four types of ionizing radiation associated with nuclear production—each with a different capacity for penetrating the body and therefore different requirements for monitoring and protection (Image 18).[36] Third, each radionuclide has its own unique biological signature. Some, like Strontium-90, tend to deposit in bone, while others prefer thyroid tissue or muscle.

So too, radionuclides differ in the amount of time they remain active in the body, and they may behave differently when combined with the chemicals that are also associated with nuclear processing. Finally, calculating exposure requires close attention to time—recording how long each body part was exposed to each type of ionizing radiation, and then adjusting for relative risk accordingly. The result of all of this, Hanford's chief radiation health scientist Herbert Parker testified, is that "man gets so subdivided between time, space, radiation types, and radionuclides *that the basic integrating sense of standards is lost*" (ibid: 17, italics added).

[35] The Atomic Energy Commission preceded the Department of Energy, which today manages U.S. nuclear weapons production and stewardship.

[36] Alpha particles will only travel short distances (about 1-2 inches) and can be stopped by a thin sheet of paper or skin, while beta particles can move up to 20 feet and require shielding made of plastic or glass. Gamma rays and neutrons can easily penetrate the body, traveling hundreds of feet from their source. Though lead, water, or concrete can shield the body from some gamma radiation, workers also manage their exposure by quota—counting how much they have received each day and doing their best not to exceed weekly and annual allowances.



18. Types of Ionizing Radiation (American Nuclear Society 2015).

Thus, though the hearings were convened to determine the administrative standards of radiation protection, much of the committee's time was spent addressing the fundamental impossibility of such an endeavor. As the official summary stated, "testimony presented at the hearings indicated that the major difficulty in translating [dose] recommendations into legal status apparently lies in the fact that such use of the recommendations is not compatible with the philosophy and rationale of the recommendations themselves" (ibid: 40). Not only is it difficult from a material perspective to accurately calculate dose, but such a calculation would fail to incorporate the necessary political, economic, and/or technical context of each exposure event. In other words, such an explicit standard would be unable to account for the fact that "acceptable exposure" is a flexible and, more importantly, a *social* determination—one deeply informed by the entwined imperatives of war and industry.

Ultimately, in an effort to balance the contradictory demands of regulatory precision and socioeconomic reality, the federal government adopted the policy of ALARA in 1975. Still in practice today, ALARA requires that radiation releases from nuclear facilities be As Low As Reasonably Achievable, "taking into account the state of technology, and the economics of improvements in relation to benefits to public health and safety, and other societal and socioeconomic considerations, and in relation to the utilization of atomic energy in the public interest" (Walker 2000: 62).

Though indemnified by this long list of contingencies, ALARA's explicit objective is to expand the margin of safety for radiological workers and the public. This is especially important for workers because it requires that nuclear facilities find "reasonable" ways to lower daily occupational dose rates below the maximum limits allowed by law. As such, ALARA is designed to give workers additional protection in radioactive space, providing "an enhanced safety factor

for what are already considered to be safe annual doses for radiation workers" (Environmental Health and Safety Center 2015).

In theory, ALARA provides a procedural framework for addressing the uncertainties of radiation protection. It recognizes that exposure produces a spectrum of hazard and acknowledges the embedded cost-benefit calculus of nuclear safety. In addition, ALARA translates these uncertainties into the more manageable language of risk—making the ambiguities of exposure concrete through statistical calculations of probability. Perhaps most importantly, it does this using the specific vocabulary of safety. It positions federal limits for permissible dose as the uppermost boundary of harm, and then renders all exposures below that level safer by comparison. As such, it produces some exposures as more protective and thus *more reasonable* than others.

At nuclear facilities, ALARA frames radiogenic exposure as a rational choice: the end result of thoughtful, informed, daily decisions made by workers and managers. It asks nuclear employees to adopt a questioning attitude, to be on constant lookout for ways to reduce their dose. As Schieber and Thezee of the Center for the Study of Nuclear Protection[37] write, successful ALARA implementation means more than simply improving procedural controls. It means engendering a "state of mind" among the workforce, creating "a shared radiological protection culture…[with a] common language and system of values" for understanding and managing nuclear risk (2000: 1). Only then, they argue, "will it be possible to achieve a socially acceptable compromise between the various risks and the resources and means allocated for their management" (ibid: 3).

This shared culture of reasoned exposure is reproduced in the daily practice of nuclear work. Before each job, managers must complete documentation that calculates and justifies every minute of occupational exposure (CH2MHill 2014). Workers then learn to stay within the boundaries of these calculations—donning personal monitoring devices on various parts of their body and cataloging their dose for each task. Critically, though it requires workers to obey procedural and managerial direction, ALARA also frames personal judgment as a natural basis for radiation protection. As the Department of Energy's nuclear safety training manual states, "acceptance of a risk is a personal matter [that] requires a good deal of informed judgment… the individual radiological worker is ultimately responsible for maintaining his/her dose ALARA" (2014: 27). As such, ALARA positions each individual as a liberal subject whose decision to engage in nuclear work is a critical part of making exposure reasonable. After all, nuclear safety is defined by an explicitly social regulatory standard: *an acceptable exposure is an accepted one*.

This logic is especially striking in personal injury cases for nuclear workers, where the law requires a concrete definition of "unnecessary" or "excessive" exposure in order to determine culpability. Ironically, though it is a federal policy, ALARA is not considered a legal "standard of care"[38] within the terms of toxic tort litigation. Indeed, as lawyers Donald Jose and David Wiedis write in *Radiological Safety Officer Magazine*,

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[37] This is a rough translation of the French *Centre d'étude sur l'Evaluation de la Protection dans le domaine Nucléaire*

[38] The "standard of care" is defined as using reasonable judgment to prevent harm to oneself or others. California Civil Code CACI 401, for example, states that "a person is negligent if he or she does something that a reasonably careful person would not do in the same situation" (2014).

> If ALARA were the standard of care, every exposure, no matter how small, could potentially make the [nuclear] licensee liable for negligence since every exposure could be analyzed with the benefit of hindsight and in most instances it would be 'possible' to have reduced the exposure. This would undermine the very stability that the regulations were designed to provide because licensees would be held liable for allowing a dose that regulations specifically labeled as permissible (2003: 24).

As such, while injured workers can claim that doses above federal maximums have caused excessive harm, ALARA's well-documented risk calculations do not hold the same legal weight. Instead, workers are expected to have knowingly assumed the risks of permissible dose—that by simply taking the job they have agreed to the terms of their exposure. As Jose and Wiedis argue, "All exposures are in a sense unnecessary to [the worker] because he could simply elect to not be a nuclear worker. Once he elects to be a nuclear worker, he consents to receive an exposure within the federal numerical limits, so that exposure cannot then be called unnecessary. It is a necessary part of the job he has chosen to pursue" (ibid: 25).

Thus, ALARA successfully performs a type of regulatory magic—it formalizes a flexible notion of risk while avoiding the legal liability of such a determination. By identifying federal dose limits as the upper boundaries of acceptability, ALARA lends authority to what remains an uncertain metric for safe exposure. Amazingly, it does this using the language of reason—creating spreadsheets, compiling data, and asking workers to make informed decisions about their own potential for injury. As such, ALARA has achieved what the 1960 Special Subcommittee on Radiation thought impossible: it has transformed an inherently imprecise and uncertain definition of nuclear safety into a broadly-accepted regulatory imperative.

CONCLUSION

In formalizing limits for permissible exposure during the Cold War, the U.S. government sought to manage the social and environmental consequences of nuclear industrial development. Indeed, the 1960 hearings of the Special Subcommittee on Radiation are explicit in this regard, asking, "How can the Nation (and the world) deal with…constantly rising levels of potential radiation exposure to the human population?" (U.S. Congress, 1960: 32). Unfortunately, the committee found it was unable to answer its own critical question. Instead, it offered the vague proposal that if contamination or exposure "became excessive," then "reactor development might have to be curtailed" (ibid).

However, in arriving at the ambiguous conclusion that production should stop at the moment its social and environmental costs became "excessive," committee members were again met with their original dilemma: the need to transform a complex and inconsistent understanding of harm into a concrete numerical value. Thus, risk-based calculations for nuclear safety were used to manufacture certainty from a set of uncertain conditions, to assert discursive control where material control was not possible.

Calculating the boundaries of acceptable risk is a political project that extends well beyond nuclear safety. Indeed, permissible exposure has been rationalized and regulated for pesticides (Nash 2006), industrial chemicals (Murphy 2006), hormones in industrial meat (Langston 2010),

Bisphenol A (BPA) in plastics (Jain 2013), and many other parts of industrialized life. In each of these cases, exposure is made reasonable through a series of cost-benefit calculations that reference a privileged understanding of the common good—the notion that even if pesticides, industrial chemicals, and radioactive particles injure some, overall they improve the collective quality of life.

Of course, the clean statistical distributions that inform risk frameworks are underwritten by a broader social and political calculus. In this sense, risk cannot be understood simply as a series of cost-benefit calculations, but as a set of social relations that give such parameters meaning (Beck 2009; Douglas and Wildavsky 1982; Slovic 1987). Like the low-hanging overpasses and tomato harvesters Langdon Winner famously describes (1986), the nuclear safety standard is a social technology that retains the politics of its creation. Thus, Cold War understandings of nuclear threat continue to inform the contemporary boundaries of nuclear safety—normalizing exposure as a natural part of modern life and work.

CHAPTER THREE

LIVING IN DOSE: NUCLEAR WORK AND THE CULTURAL POLITICS OF INJURY

Living in Richland is ideal! We only breathe tested air.

—Richland resident, 1954[39]

One can picture the entire population of Richland lying unclothed on the ground for one day. There would be about 25 identifiable particles in contact with the skin; not more than three would be in an activity range that could produce a significant effect; not more than one would probably produce an effect…At the worst, there would be a small necrotic area, perhaps comparable with the effect of plunging a lighted match head to the skin. My best guess is that this would not happen in one day's contact with the hottest known offsite particle…Pig skin and human skin are sufficiently alike that if the pig can wear a 400 mrad/hr particle for five days, I would be willing to wear one for one day.

—Herbert Parker, personal communication regarding, "Control of Ground Contamination," 1954[40]

TESTIMONY

Thursday evening, after dinner, workers bring their families. They find seats, or stand when there are no seats left, offering chairs to the elderly and infirm. They sign up to speak, printing names on index cards and placing them one on top of another. At the front of the room is a long table draped in royal blue cloth, a slender microphone at its center, an American flag at its back. The air is silent and thick with the warmth of over-crowded bodies and the anticipation of long held secrets.

The Assistant Secretary of Energy walks to a podium and holds a microphone before burgundy tie and bearded lips. He tells them their government wants to know if it has hurt them. He tells them, "statistics are people with the tears washed off," that there is more to the story than numbers can say. He tells them he is there to listen.

The first to the table is an elderly man with parted white hair, glasses, and lung cancer. Next, a daughter speaks for her father who died of bone marrow disease at age fifty-nine. Third, a middle-aged man wearing anger and a plaid shirt describes the tumors that grew on his hand, lung, and adrenal gland. He holds up a form he was required to sign allowing him to exceed his

[39] This is part of a longer statement that reads, "There is a definite possibility that information, or rather misinformation, on the off-site condition will leak to the public in the near future. Not all residents will be as relaxed as the one who was recently quoted as saying, 'Living in Richland is ideal! We only breathe tested air.' To prepare for adverse questions, a suitable press release is being developed to be held in readiness" Herbert Parker, *Status of Ground Contamination Problem*. September 15, 1945 Document HW-33068. (Box 4, Folder 4.3)

[40] Document HW-32808, US Department of Energy Public Reading Room, WSU-Tri-Cities.

lifetime dose of radiation. Four: pancreatic, lung, and adrenal cancer. Five: prostate cancer and asbestosis. Six: lymphocytic leukemia. Seven: Asbestosis and Beryllium disease.

The succession of stories continues for hours as hundreds of bodies sit before the microphone, *"I've been diagnosed with cancer of the pancreas with six weeks to live, God save me."* Hundreds of workers lick lips and clear throats that catch with nerves and emotion, *"They say the only thing they can do for me is a lung transplant. Any of you got a lung they want to get rid of?"* Hundreds of hands unfold prepared statements to be read aloud, *"I did my work and I did it proudly, what will you do for us?"* Hundreds of people, indelibly marked by the bomb, take a deep breath. And speak.

* * *

On February 3, 2000, more than five hundred Hanford workers and their families crowded into Richland's Federal Building auditorium. At the request of the U.S. Department of Energy, they came to the front of the room one by one and talked about their health problems. With voices that alternately vibrated with pride and cracked with anger and sorrow, workers testified to their shared history of exposure and its effect. For many, it was the first time they had spoken publicly about their illnesses, a subject long considered weak and unpatriotic in this company town (Gerber 2007). Their testimony continued for more than five straight hours, ending at almost midnight.[41]

This public airing of grievances in politically conservative, pro-nuclear Richland was historic. As the *Los Angeles Times* wrote the following Saturday, "no one ever thought they'd see it happen. Not in this town" (Murphy 2000: A1). This town that gave birth to the bomb. This town that coaxed Plutonium from Uranium "slugs"[42] for more than four decades to power the nation's nuclear arsenal. This town that shops at "Atomic Foods" and cheers for a high school football team called "The Bombers," whose helmets are decorated with mushroom clouds. This town that held a candlelight vigil when Hanford's final reactor shut down, marking the end of Cold War weapons production. This town that now lives and works alongside the nation's largest nuclear dump.

Richland's evening of testimony came in response to a draft report by the National Economic Council. Released by the White House on January 29, 2000, the report found "credible evidence" that American nuclear weapons workers "may be at increased risk of illness" from exposure to ionizing radiation and chemical toxins (Warrick 2000). The report marked a significant reversal in the federal government's official telling of nuclear history. It stated publicly for the first time that workers' bodies had been sacrificed in the name of national security and economic expediency. Richland's *Tri-City Herald* wrote that the report "hit Hanford like a lightening bolt from one of the sudden summer storms that sweep over the nuclear reservation" (Cary 2000: A1). Perhaps a more fitting analogy would be: the news hit Richland like a bomb.

In the months that followed, the Clinton Administration promised a new era of transparency. As Energy Secretary Bill Richardson told the *Washington Post*, "the Department of Energy is coming clean with its workers" (Warrick 2000: A2). On April 13, Vice President Al Gore announced a

[41] A video of these hearings can be seen at http://www.youtube.com/watch?v=2zWqHzEw48M

[42] Workers call uranium fuel rods "slugs" because of their long cylindrical shape.

new initiative for compensating the sick and injured, saying, "today this administration begins the process of healing by admitting the government's mistakes, designing a process for compensating these workers for their suffering, and by becoming an advocate for Department of Energy workers throughout the nuclear weapons complex" (ENS 2000). True to its word, the federal government passed the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) on October 30, 2000, establishing a federal workers compensation program for individuals who had been exposed to ionizing radiation in the course of their career.[43] The Act recognized workers at more than 300 Department of Energy facilities across the United States.

Today, more than fifteen years since Richland's historic hearing, many nuclear safety procedures within the DOE complex have been updated and more than 66,000 compensation cases have been paid through EEOICPA (DOL 2014). However, despite these notable efforts toward regulatory reform, the federal government has been unable to solve the fundamental paradox of nuclear safety: that some level of exposure is unavoidable when working with nuclear materials, and that any level of exposure comes with an associated biological risk. In short: *injury is an operational necessity of nuclear industry*. Thus, nuclear safety can never mean total protection for workers. It can only ever be the level of exposure that has been deemed acceptable relative to the imagined benefits of radiation. Indeed, this necessary wounding of the worker informs the most basic metrics for nuclear safety. Occupational dose rates are calculated using a specific definition of "reasonable" harm. For nuclear workers this begs a very practical question: How do you stay safe in a system that requires your exposure in order to function?

In this chapter, I examine how Hanford workers negotiate the uncomfortable contradiction of safe injury. I consider the intimate daily practices of radioactive safety and the sensory politics of nuclear work. I begin by discussing how exposure standards are translated into "dose"—a calculated dispensation of exposure over time that seeks to forestall the inevitability of harm. Next, I explore the chronic and uncertain health effects of radiogenic exposure. Tracing the progression of an "impossible" illness following a high-level waste spill, I discuss how workers learn to live with bodies that have been remade through nuclear encounter. So too, I examine how uncertainty plays to power in remediation practice, positioning worker error as the cause of exposure events and masking the structural necessity of worker injury. Finally, I consider how both injury and compensation are integral to the broader social logic of nuclear remediation, as structures like EEOICPA provide official narratives of sacrifice and redemption in the spectacle of post-Cold War reckoning.

LIVING IN DOSE

For nuclear workers, exposure is translated from theory to practice using specific calculations of "dose"—numerical values that represent the biological impact of radiation.[44] Dose provides a common language for articulating exposure, for measuring the amount of radioactivity each

[43] In 2004, Congress approved an expansion of the program to include illnesses associated with chemical exposure as well.

[44] The most common unit of measurement for radiogenic exposure is the "rem"—a calculation of biological impact from radioactivity that adjusts for the penetrative capacity of each type of ionizing radiation.

body has received, and for expressing the relative probability it will result in injury. The Department of Energy, for example, uses dose to instruct workers in risk interpretation. In its *Radiological Worker Training Handbook*, the DOE states,

> The risk of cancer induction from radiation exposure can be put into perspective…the current rate of cancer death among Americans is 20%. Taken from a personal perspective, each of us has about 20 chances in 100 of dying of cancer. A radiological worker who receives 25,000 mrem[45] over a working life increases his/her chance of dying of cancer by 1%, or has about 21 chances in 100 of dying of cancer. A 25,000 mrem dose is a fairly large dose over the course of a working lifetime. The average annual dose to DOE workers is less than 100 mrem, which leads to a working lifetime dose (40 years assumed) of no more than 4,000 mrem (2014: 26).[46]

This passage is accompanied by a table designed to help workers "put potential risks into perspective when compared to other occupations and daily activities" (2014: 16). Juxtaposing a range of industries and personal practices, the table allows workers to compare the relative decrease in life expectancy from things like smoking cigarettes, working in agriculture, or being struck by lightening (Image 19).

Health Risk	Estimated Loss of Life Expectancy
Smoking 20 cigarettes a day	6 years
Overweight (by 15%)	2 years
Alcohol consumption (U.S. average)	1 year
Agricultural accidents	320 days
Construction accidents	227 days
Auto accidents	207 days
Home accidents	74 days
Occupational radiation dose (1 rem/y), from age 18-65 (47 rem total)	51 days
(Note: the average DOE radiation worker receives less than 0.1 rem/yr)	
All natural hazards (earthquakes, lightning, flood)	7 days
Medical radiation	6 days

(*References 1 and 12 of the PMG*)

19. Estimated Loss of Life Expectancy Table (DOE 2014).

At a decreased life expectancy of only 51 days, the table positions occupational exposure to radiation as safer that simply spending time at home, where accidents decrease the average

[45] A mrem (or millirem) is one thousandth of a rem.

[46] What this statement fails to acknowledge is that the federal limits for permissible dose to nuclear workers is actually 5,000 mrem *per year*—meaning a worker could receive a lifetime dose of 200,000 mrem (using the DOE's 40-year estimate) and still be considered safe within the terms of the law.

lifespan by 74 days. Asking workers to therefore consider the big picture, the *Training Handbook* elaborates,

> The estimated risk associated with occupational radiation dose is much less than some risks widely accepted by society. The risk of work in a radiation environment is considered within the normal occupational risk tolerance by national and international scientific groups. However, the acceptance of risk is an individual matter and is best made with accurate information…It is hoped that understanding radiation risk and risk in general will help you to develop an informed and healthy respect for radiation, and that your understanding will eliminate excessive fear (ibid: 27).

This not only has the effect of normalizing exposure, but it assigns concrete numbers to what are fundamentally uncertain metrics for radiogenic injury. So too, it erases the structure in which nuclear work is done, assuming that workers can simply choose to accept or decline the risks of exposure at will.

This complex relationship with exposure is, in part, a consequence of conceptualizing threat through the lens of risk. As Langdon Winner argues in *The Whale and the Reactor*, there is a subtle yet critical difference between using words like "danger" and "peril" to describe an issue versus using "risk." According to Winner, the word risk "carries a certain baggage, a set of ready associations" (1986: 145). Risk is something one can choose to "take" based on the relative probability of cost and benefit. It evokes a liberal subject whose decisions are informed by rational calculation (Porter 1986). In addition, risk affords statistical comparison between incongruous activities like driving a car and working in a radioactive environment. If one is willing to accept the relatively higher risk of an automobile accident, for example, how can one argue that the relatively lower risks of nuclear work are unacceptable? As such, risk discourse creates its own conditions of possibility for rational decision making (Clarke 1999). Choices that do not reflect these terms are considered suspect, the result of fear and/or misinformation.

What does it mean to embody such an ambiguous standard? How do nuclear workers negotiate the uneven terrain of risk, reason, and relativity? For some, being a nuclear worker means accepting the notion that safety can co-exist with risk—that the presence of one does not necessarily negate the other. As one Hanford worker told me,

> We know how to protect ourselves, how to be safe. Now, we still do things, you have to take risks. Yes, we do have contaminations, we do have people get dose, but we try to limit that. We're out there monitoring our exposure, monitoring our dose, but to do this you have to have a certain buy in of understanding. I do work in the nuclear industry and there are some times that we're going to have proceed forth with a certain amount of risk. And that's just life. That's just how it goes. We do that every single day anyway. And I realize that the catastrophes can be enormous, I fully understand that, but we have a pretty good handle on it.[47]

For others, it means learning to embody the specific parameters of radiation protection, calibrating physical movements according to strict procedure in order avoid unnecessary dose.

[47] Personal Interview, Benton County. April 17, 2012.

"We have to be in constant control," one worker told me.[48] "It's not just cutting up cheese and turkey, for crying out loud!" another said, "If I'm going into some nasty crap, I gotta have a decent work plan, we gotta know what we're doing. If not, your risk is going to shoot up astronomically and you're going to have a lot more uh-ohs out there."[49]

Because radiation is insensible to the human body, protecting oneself means developing a working knowledge of the invisible, using procedural directives and radiation sensors to mediate the relationship between one's body and environment. As retired Hanford worker Wakefield "Wakie" Wright described it, "The radiation danger was always with us. We were taught to obey our instrumentation, like flying an airplane. If your instrument says you are flying straight and you think you are flying upside down, you better think you are flying straight" (Sanger 1995: 189). Historian Joy Parr examines this distinctive pedagogy of radiation protection, a theoretical and practical training in what she calls "embodying the insensible" (2010). She describes how workers learn to understand sensory perception through technological proxy—how they educate their bodies to experience instrumental readings "as sensation, as a form of tacit knowledge with the same credibility as touch, taste, or smell" (ibid: 68). In addition, embodying the insensible means developing a somatic awareness of occupational exposure limits—understanding radiation through bodily quotas and calculating and cataloging one's accumulated dose. It requires learning to *live* federal regulations for radiation protection, fine tuning one*self* to the statistical reasoning of nuclear industrial risk.

This embodied practice is something one learns over time. It requires years of experience working with nuclear materials, developing an instinct for how radiation travels through space, and forming habits of movement that minimize exposure. "You have to do the work to really understand what its like," one worker told me, "new people don't understand how the systems interact, don't understand what specific things mean, and don't understand the interactions."[50] Another worker echoed her by saying, "This is stuff you learn over time, over years of knowing history and knowing what you're dealing with. These new kids think they know everything, and its like, yeah, you're twenty-two years old, you're not really trained. You just spent six months in a classroom doing calculations. Well, this is a high-rad area, stuff you don't have any clue about."[51] Still another person told me,

> There's been a deliberate shift to get younger, less experienced workers that are cheaper into the work force. No pension, not complaining as much, but they don't know what they're dealing with. They're ARRA[52] hires off the street—very little training and boom you're a Hanford worker. They are deliberately given skilled jobs like operators used to do, taking over a lot of that work and the operators are like, no you can't have them do that, they're not trained and you're putting them all at risk, but they are losing those fights. That's how Hanford is being run now. And it scares the hell out of a lot of people

[48] Personal Interview 1, Leavenworth, WA. October 2, 2013.
[49] Personal Interview, Benton County, WA. April 17, 2012.
[50] Personal Interview, Benton County, WA. April 17, 2012.
[51] Personal Interview 1, Leavenworth, WA. October 2, 2013.
[52] The American Recovery and Reinvestment Act (ARRA, also known as the Obama Stimulus package) brought many new workers to the site. Hanford workers talk about this often—how, ironically, the ARRA funds made for much more dangerous working conditions on site.

> who are retiring out of there saying I don't even want to go to work anymore. I'm worried about what's going to happen. If someone doesn't know what they're doing it can be dangerous. I'm not saying that's the way it is all over the place, but I think those incidents happen on a regular enough of a basis that people are concerned.[53]

Workers argue that an embodied knowledge about place and practice comes with an increased measure of safety. As one longtime worker said, "We have procedures. We have a certain way that we work around here and we do it for a reason: to keep people safe. I want to go home safe. I want to go home to my kids at the end of the day."[54] At the same time, experienced workers recognize that this safety is not absolute. Many acknowledge that even safe practices cannot prevent eventual radiogenic impact.[55, 56, 57] As one worker told me,

> Well, you know, with radioactivity, you get a chronic exposure to that eventually. I mean, it's a cancer-causing agent. The scary part is I've been [here] a long time. And you know, I'm at that point, that latency period, you know. About 20 years. You know, where stuff starts happening or people start getting sick or things just aren't right. And so that worries me, it's like, gosh. But you know, the damage has already been done. I mean, I suppose I could quit now and there would be no more damage for me from this day forward, but…[58]

So too, the logic of safety as administered through dose is often undermined in the recording process. The same worker remembers receiving a dose of 600 mrem in one day while she was pregnant—100 mrem more than the total amount allowed for her entire nine-month gestation period. "They never assigned me the dose because then I would have been overexposed for a pregnant worker," she told me. "They said that there was probably just something wrong with my dosimeter, that there was a pinhole—a microscopic pinhole in my dosimeter that nobody could see—that would cause it to malfunction. I said, well that's crap. I'm not buying that. And I've gone back and said, hey, you know, I'm curious about this. You know, I was pregnant! And they said, no they have no record of it. None whatsoever."[59]

Another recently retired worker told me,

> When I would dress out,[60] I was told that my [dosimetry] badge went on the inside of my coveralls. My pencil dosimeter, if it was issued, was in my pocket on the outside. But my badge that had the secondary dose on it, was inside my coveralls…That was the way you dressed out because they didn't want you crapping up[61] your badge. 'Don't crap up your

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[53] Personal Interview 2, Leavenworth, WA. October 2, 2013

[54] Personal Interview 1, Leavenworth, WA. October 2, 2013.

[55] Personal Interview, Seattle, WA. December 13, 2011.

[56] Personal Interview, Richland, WA. May 10, 2012.

[57] Personal Interview, Richland, WA. May 9, 2012.

[58] Personal Interview 1, Leavenworth, WA. October 2, 2013.

[59] Personal Interview 1, Leavenworth, WA. October 2, 2013.

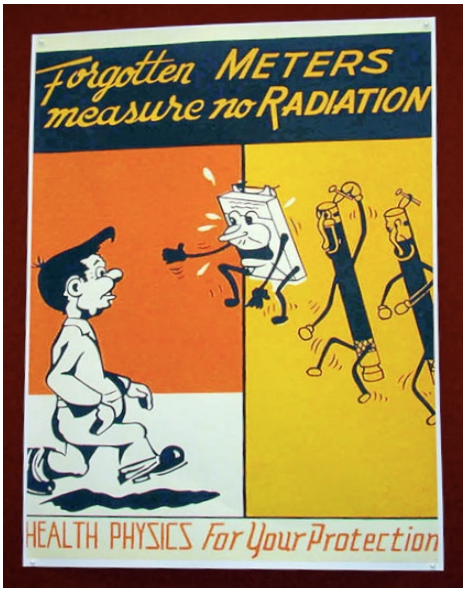
[60] "Dress out" is slang for getting suited up for radioactive work.

[61] "Crap up" is slang for getting contamination on something or someone.

> badge,' they said. What's more important here, a two-dollar badge or your life? The badge! (*laughs sarcastically*).[62]

As workers, these individuals have to continually negotiate the difficult cognitive territory of safe exposure. They have to obey strict procedural direction and comply with dose limits in the name of their protection (Image 20), while also knowing that these structural requirements not only fail to prevent the eventual injury of nuclear work, but they may also be undermined by management at any time. As such, they have to learn to embody both the logics of nuclear safety and its embedded contradictions.

This structural dynamic is especially pronounced when accidents happen at Hanford. In these moments, dose is an "event" rather than a normalized daily practice. However, even when an accident increases the symbolic power of exposure, associated injuries often remain unthinkable within the official terms of nuclear impact. I examine this more closely in the following section through the lens of Hanford's S-102 spill. The spill took place in the middle of the night on July 27, 2007 when a dilution hose that had been pumping water into waste tank S-102 suddenly reversed flow and sprayed nuclear material onto the ground. Several workers on duty that night smelled the waste and called it in to their supervisor, taking dose as they waited for the official order to take cover. Tracing the experience of a Hanford worker named Karen following the S-102 accident, I consider the lived experience of radiogenic injury and how sickness is made intelligible (or not) in the context of nuclear toxicity.

a) 

b) 

20. These radiation safety posters remind DOE workers to wear monitoring devices while on the job. In image a, we see two types of cartoon badges: a rectangular dosimetry badge and two longer pencil dosimeters. In image b, a young Ronald Reagan affixes a dosimetry badge during a visit to the Hanford Site. (Oak Ridge Associated Universities 2015).

[62] Personal Interview, Richland, WA. May 9, 2012.

THE POLITICS OF IMPOSSIBLE ILLNESS

"When I woke up the next morning it hurt to breathe," Karen told me. "It hurt every breath in and every breath out. I'd never had that happen before. So I start to worry."[63] The doctor did the customary tests included in any physical examination—he took blood, sampled urine, listened to her heartbeat and breathing, checked for high cholesterol. Then he told her to return to work, told her she looked fine, told her to go to the Emergency Room if it got worse. It was the equivalent of "take two Aspirin and call me in the morning"—strange, considering Karen had been exposed to poisonous vapors for several hours the night before. The doctor did not test for the possible deleterious effects of chemicals she could have inhaled, or radioactive exposure she could have received. The S-102 spill was so recent that they didn't have much data. "He didn't know what chemicals to test for," she said.

Back at work, Karen found her orders were to return to the tank farms. To return to the spill perimeter where she had spent much of the previous night, inadvertently inhaling chemical vapors that would permanently alter her body. Incredulous, she refused. Amazing, she thought, disquieted, "the blood tests are not back yet, but they're sending you into the hot zone!"

Later, Karen's test results came back normal, but her symptoms persisted. She developed extreme sensitivities to certain smells. A lit cigarette or a neighbor's perfume could initiate respiratory failure, sending her to the Emergency Room. Things got so bad she had to stop working. Every day tasks like grocery shopping became a challenge, an exercise in envisioning the invisible, as she tried to anticipate the geography of potential hazard in each building she entered.

She was not alone. Other tank farm workers present on the night of the spill developed similarly ambiguous symptoms, frustrating sets of amorphous illnesses that, though they evaded definition, were real enough to make normal life unmanageable. In each worker's case, the Department of Energy denied a causal relationship between their symptoms and their exposure to S-102 waste.

Why has the Department of Energy denied the validity of these illnesses? Karen and her co-workers on the night of the accident were exposed to toxic vapors. That much is well documented. They were present at the site of a nuclear spill involving 85 gallons of high-level radioactive and chemical waste, and exposed to toxic materials for many hours before the Take Cover alarm was initiated. And yet, they can't prove causality, they can't prove harm. How can we explain this apparent break in logic? How is it possible that illness can *not* be taken seriously after a nuclear accident? Furthermore, why is it the onus of the worker to prove harm?

That workers must evince their illnesses to the entities responsible for their contamination reflects a deeply unequal power structure at Hanford. Risk and nuclear safety are managed in such a way on site that the burden of responsibility for accidents often falls on workers' shoulders, rather than on the officials who approved the procedure. It also reflects a governmental fiction that risk-

[63] Quotes from Karen (pseudonym) in this chapter were drawn from a telephone interview on December 1, 2009. However, this and other telephone interview cited in this chapter represented subsequent conversations with people that I spoke with at length in person as part of my field work.

free nuclear management is possible. These structural inequalities and fictive expectations impede workers' struggles for compensation.

Hanford's denial of harm also reflects a bias in the medical community about what kinds of illnesses are valid. Karen's sickness exists outside the bounds of biomedical logic, her symptoms simply do not conform to scientific conceptions about normal physical function. When her body reacts violently to one brand of perfume, but not another, it does so in a "domain of supposed impossibility…in a condition outside of 'disease'—that is, as an invalid bodily state" (Murphy 2006: 152). In effect, the inability to taxonomize her bodily functions has removed her symptoms "from the realm of legitimate corporeal illnesses" (152), a delegitimization that has made her ineligible for worker's compensation and health coverage. It has also made legal action more difficult—for how does one hold a company or corporation (or the Department of Energy) legally responsible for a medical condition that, officially, doesn't exist?

In addition to the unusual symptoms that accompany nuclear exposure, the seemingly random pattern of affliction among workers complicates causal explanation. Not everyone exposed to nuclear materials during the S-102 spill became ill. One person stood close enough to touch the waste and yet he didn't develop symptoms. Another worker, who was a mile away that night, did. Karen likened working in a radioactive risk zone to eating an enormous chocolate chip cookie with only a few chocolate chips in it. You can take many bites before you hit a chocolate chip, or you can encounter one in the first bite. Radioactivity is a strange beast, impossible to truly anticipate. You never know when you will get a bite of it, she told me, and how it will affect you if you do.

Among the confounding elements of nuclear exposure, is that its effects are inconsistent. Some days, Karen is more sensitive to chemicals than others. The capriciousness of her symptoms weakens her fight for legitimacy and compensation. In effect, when she feels better, she undermines her own cause. "It makes you look like a liar," she told me. Hanford has been known to have sick workers followed by private investigators—documenting their activities throughout the day and highlighting instances when they imagine the worker *should* have a symptomatic reaction under the conditions of their "supposed" illness. Thus, every day activities like pumping gas, or getting a pedicure (both odorific exercises) become evidential moments. The simple act of living becomes an exercise in credibility.

Not only is erratic bodily reaction, then, a legal liability, it also becomes a source of guilt and self-doubt. It creates a paradoxical relationship with one's own body where legal and even personal legitimization depends on a set of inconstant (yet, very real) symptoms. A confusing emotional connection between illness and wellness is the inevitable result. Recovery becomes a contradictory act.

Uncertainty as to the "true" effects of nuclear poisoning on workers and the environment is an everyday reality of nuclear remediation. Hanford workers and residents of the surrounding community understand and process their proximity to hazardous waste in different, and often paradoxical ways. A large percentage of the local populace denies the risks associated with nuclear production, rolling their eyes at environmentalist rhetoric, some even sporting T-shirts that boast, "A little dose doesn't scare me."

So too, daily life in the Hanford region normalizes risk in routine ways—the area's drinking water comes from the Columbia River *after* it has passed through the nuclear reservation, the atomic symbol adorns park benches and beer mugs, the football players have mushroom clouds on their letterman jackets (Image 21). Each piece of nuclear culture reflects a shared history of weapons production, and the collective feelings of pride and honor integral to that effort. The Hanford community spent more than forty years preventing Soviet attack by producing Plutonium. In the collective regional imagination, nuclear production kept the nation safe. The conceptual disconnect that such efforts to protect the United States could have simultaneously injured its citizens with radioactive poisons, is evident in the community. This historical production of nuclear risk as pertaining to communism rather than contamination plays a central role in delegitimizing radioactive injury.

21. The Richland High School "Bombers" gear. The school motto is "Proud of the Cloud!" (Photo of Helmet from bomberfootball.org and photo of bumper sticker by author).

Negotiating the difficult cognitive terrain of daily interaction with a deadly substance also influences how Hanford workers interpret their injured colleagues. In Karen's words, "workers tell themselves, 'if I really believe that it's hazardous enough for her to get sick, I should quit immediately. But I can't afford to so…'". Of course, many people at Hanford understand that their jobs involve risk, but they have faith in safety procedures. Psychologically, it is easier to doubt the validity of the illnesses that occur after exposure events like S-102 than to acknowledge the possibility of danger. "Because," as Karen told me, "to keep working out there that's what you have to tell yourself." You have to believe that it's safe.

THE CULTURAL POLITICS OF NOT KNOWING

Assuring worker health and safety at Hanford means managing uncertainty as much as managing the radioactive materials themselves. Much of the site's high-level waste is stored in leaky underground tanks, and, short of pumping the materials above ground, it is difficult to ascertain what types of chemicals and radionuclides those tanks contain. The scope of the

problem at Hanford is so great, and managing its materials so complicated, the potential for nuclear accidents, mistakes, and mismanagement is very high.

The Department of Energy will not approve a project at Hanford unless the risk of hazard to workers and the surrounding community is 1 in 10,000. This is an unthinkably high expectation, especially for a nuclear facility like Hanford. It is simply not possible to function at Hanford without incurring some level of risk. The Department of Energy's strategy for dealing with this logical inconsistency lies in a near religious reverence for the power of procedure. In order to maintain the fiction of control, every step of every remediation project is carefully constructed, detailing what order to flip switches, open valves, close doors, etc. As Karen told me, "[Hanford engineers] write procedures—step by step—that say what you will be doing exactly…There are safety based rules and regulations and you make sure you don't ever get out from underneath of them."

Creating procedure also involves some level of decision making about what risks are necessary to manage. This places nuclear engineers and DOE managers in the position of determining what is possible, allowing managers almost divine predictive capacity. Personal and institutional biases about the relative hazards of radioactivity or chemical vapors is thus integrated into remediation procedure. Because a causal connection between chemical inhalation and illness has not been validated by the appropriate scientific experiments and nuclear experts (and has therefore been deemed "incredible"), guarding against chemical vapors may not be included as part of the procedure. Workers may or may not be required to use artificial air when working in potentially vaporous places, for example.

The nuclear accident at S-102 represented a moment when radioactive waste acted in a way that procedure-creators didn't anticipate—the waste's actions exceeded the possible. The material in tank S-102 escaped through a dilution hose that had been adding water to the toxic sludge in the tank, easing the waste pumping process. However, in this instance, the waste changed physical form. It created a cement-like substance around the bottom of the pump, clogging it, and forcing waste up the dilution hose (a piece of equipment that had not been designed to hold high-level nuclear materials). "In 30 years of experience at Hanford, I had never seen anything like that before," Karen told me. "The waste formed its own containment, its own vessel, the hose gave out before it did." Another worker told me, "The reason they had a problem was they decided it [waste going up the dilution hose] was incredible. And you don't put in extra safety features when you think it's incredible."[64]

Assuming the stance that risk-free nuclear remediation is possible places the burden of responsibility for mistakes (and for their own illnesses) on workers rather than on the Department of Energy. As Karen told me,

> If they [DOE] say do it safe, what they mean is do it safe and do it as fast as you can. As long as that can be done and get something accomplished. But don't be safe at a standstill. But that contradicts itself. Hanford has this zero accident mentality—they say zero accidents, they say that's what the goal is. Well, that's an unachievable goal. But

[64] Telephone Interview, December 16, 2009.

> people [at DOE], have said, no, we really mean that. Well, sorry you can't get anything accomplished then. So does that mean, just don't tell us? Just tell us it's safe?

Thus, workers have to negotiate the conflicting messages they receive from upper-level management, and when accidents happen, those workers inevitably take the blame. Karen described a post-accident conversation like this,

> Worker: "But I thought you knew it was happening."
>
> DOE Manager: "Oh no, I would never approve that."
>
> "Well," she told me, "they oked it by not asking."

Blaming accidents and mistakes on worker error—on improper adherence to procedure—rather than on structural deficiencies means that Hanford's institutional framework evades scrutiny. Thus, systemic changes are politically unnecessary and bad cleanup policy persists.

Calculating risk is inevitably complicated by personal bias, economic incentives and constraints, and political pressure. However, even if it *were* possible to conduct risk assessment from a neutral position, inadequate data makes creating safety protocol virtually impossible. The S-102 tank, for example, was part of a tank "stabilization" project that transfers high-level nuclear waste from leaky, single-shell tanks to newer, double-shell tanks where it can await treatment and disposal. Retrieving nuclear waste from underground tanks at Hanford is no easy task. As one Department of Ecology official told me, "it's like trying to suck up an Olympic-sized swimming pool full of peanut butter with a coffee-stirrer straw."[65]

Even when methods are devised for successfully retrieving waste from holding tanks, its chemical composition remains ambiguous—no one knows for certain what nuclear materials the storage containers hold. As Karen said, "If anyone ever tells you they know what's going on, they're either ignorant or a liar. Because no one really knows. You can't see in there. You're doing it blind. It's like sticking a straw in a Styrofoam Big Gulp container"—you can't look before you sip. Tank waste stabilization is further complicated by the fact that chemical properties change when various materials interact over time. Thus, waste records from decades past may hold little information about the substances currently stored on site.

This, again, highlights a central paradox of management at Hanford. Nuclear policy requires a level of certainty to assess risk and create procedure, however, it is managing fundamentally uncertain materials. The frustrating reality is that those in charge of managing nuclear waste do not acknowledge the basic irony of their task, but continue to operate as if radiation and risk are containable within the bounds of mathematical modeling and carefully planned procedural controls. Hanford workers and the surrounding environment bear the brunt of such willful ignorance.

In response to growing concern about chemical vapor inhalation from tank waste, an expert committee of non-Hanford affiliated academics and industry professionals convened to assess

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[65] Personal Interview, Richland, WA. August 21, 2006.

chemical hazard and risk methodology at Hanford. The committee concluded that the best way to protect Hanford workers is to reduce uncertainty within remediation procedure. However, in their assessment, they failed to understand uncertainty as a complex embodiment of social relations and practices. They failed to recognize the structural power of uncertainty.

The relationship between certainty and uncertainty at Hanford is complex and often contradictory. Indeed, remediation practice is already engaged in reducing uncertainty on a daily basis. However, that act of reducing uncertainty, controlling the impossible, dictating the possible, produces a fictional reality in which workers must operate. In some cases, the practice of reducing uncertainty actually creates the situation in which workers are to blame for nuclear accidents. Certainty that Karen's illness was caused by S-102 waste would change her life for the better. However, it was also certainty (which considered the S-102 spill to be impossible) that created the conditions for her exposure. It is within the very bounding of certainty that Karen finds both her exclusion and the potential for her salvation.

CONCLUSION

When hundreds of Hanford workers and their families gathered and gave testimony in Richland's federal building auditorium, their stories revealed more than a shared history of illness and injury. For many, exposure was not just a violation of their body, but of their rights as American citizens. At stake was the meaning and value of their sacrifice, whether their wounds carried social, political, and economic weight. As one worker told the Secretary of Energy, "There's a lot of us who worked hard for a lot of years. We're not looking for a free lunch. We're not interested in a big money claim. But you don't want to be left with nothing, with no health to go get another job. We just want enough to get by and to live a dignified life for what's left of it" ("Public Hearing" 2000). Another worker echoed him angrily, saying, "The Department of Energy is spending over six billion dollars to cleanup the contaminated waste. A billion of that is coming to the Hanford Site. We're only asking that the Hanford workers get treated just half as well as the dirt" (ibid).

In *Life Exposed,* Adriana Petryna describes how radiogenic injuries following the Chernobyl disaster became the currency through which exposed individuals negotiated survival in the post-Soviet era. Identifying the legal boundaries of health and suffering, she argues, produced new forms of "biological citizenship," where injury and illness became "the basis for staking citizenship claims" (2002: 5). Likewise, Hanford workers called attention to their injuries as a means of re-negotiating their citizenly rights and privileges. Evoking liberal ideals as old as the nation, workers contested what they saw as an unequal relationship between their individual bodies and the body politic.

Moreover, by telling their stories, workers raised broader questions about the nature of citizenship in the nuclear state. Until 2000, nuclear weapons workers within the Department of Energy complex did not receive special benefits for their role in wartime activities.[66] Though they produced the technologies of war and were exposed to its byproducts, they were not

[66] The exception to this are Uranium Miners who have been eligible for compensation through the Radiation Exposure Compensation Act (RECA) since 1990.

afforded veteran status. As such, they lacked the political recognition and access to social and economic programs promised their Department of Defense counterparts.[67] When Congress passed the Energy Employees Occupational Illness Compensation Program Act (EEOICPA), it was an attempt to expand the legal geography of the nuclear battlefield. Indeed, its passage created a new bureaucratic subject: the "atomic weapons employee," an individual whose sacrifice in the service of the nuclear arsenal now officially merited compensation (U.S. Congress 2000: 5).

EEOICPA renders injury legible through a complex valuation of pain and suffering. As a compensatory system, it seeks to "ensure fairness and equity" (ibid: 2) for injured workers within the socioeconomic terms of progress, profit, and national security. As such, EEOICPA is framed as a rational mechanism for remedying the unequal social relations of nuclear production. As its legal subject, the atomic weapons employee submits her wounded body as evidence that she has not received adequate protection from workplace hazards. Subsequent compensation is then distributed (or not) according to the logic of the marketplace that gives her labor value—where injury is imagined to be "'undone' through the monetary award that will in a rough sense 'buy back' what it has taken" (Jain 2006: 12).

Of course, as Elaine Scarry argues, "compensation is only a mimetic rather than an actual undoing" (1985: 300). While the financial and medical assistance that EEOICPA offers may prolong and improve workers' lives, it does little to address the uncomfortable reality that injury is necessary to nuclear production. Instead, nuclear safety regulation is based in the logic that some level of exposure (and associated injury) is integral to the nation's security. This rhetoric of honorable sacrifice is espoused by non-governmental advocacy organizations as well, where a celebratory narrative of the "Cold War Warrior" is frequently evoked to justify compensation claims (Krupar 2013) (Image 22).

22. Cold War Patriots mailer (CWP 2014).

[67] Of course, as many scholars have noted, having veteran status does not necessarily mean access to adequate health care and social and economic assistance.

However, this narrative erases the state's complicity in creating the conditions for worker injury. Asking the federal government to determine the need and value of compensation, fails to acknowledge the ways that it is profoundly invested in *producing* the injuries it adjudicates (Brown 1995). As Lochlann Jain argues, "The state makes injury visible only on its own terms, through its own mechanisms. Asking the state to protect against injury deeply legitimizes the state [even] as it disavows its role in injury production and distribution" (2006: 56).

In this chapter, I have examined the deeply political ways in which wounding is central to nuclear production. These wounds are reproduced through both their banality and their invisibility, as the normalization of exposure makes it more difficult to see radiogenic impact. Indeed, the social politics of nuclear safety are as much about "making bodies and behaviors more predictable and knowable as it is with creating—intentionally and inadvertently—spaces of non-knowledge and unpredictability" (Petryna 2002, page 13).

This productive tension between the known and unknown is most powerful in the lived, every day sense. For, as Foucault reminds us, control is made possible through each subject's interpellation into regimes of conduct (1973, 1977). Nuclear waste and structures of remediation, then, represent a distinct set of social relations. Through the compensation process, workers' bodies become official remnants of the Cold War, integral to the spectacle of post-war reckoning. Identifying certain injuries as valid (and others as invalid) allows the U.S. government to manage the scale of the bomb's aftermath. By embodying the administrative categories of sacrifice and redemption, therefore, the "atomic weapons employee" is critical to the broader social logic of nuclear remediation.

CHAPTER FOUR

WILD AND SCENIC WASTELAND: CONSERVATION POLITICS IN THE NUCLEAR WILDERNESS

These fragments I have shored against my ruins.

—T.S. Eliot, The Wasteland

Tracy stands on a mound of steaming garbage at the city landfill and tries to get used to the smell. Geiger counter in hand, she moves carefully between rolling hills of trash, feeling the unstable squish of each step on decaying ground. Searching. She steps over a plastic bag that has burst in the middle, spewing chicken bones, oily napkins, and a partially melted spatula. She checks the radiation count—normal—and wishes she could plug her nose. She moves on. Finally, beneath a rusting three legged chair she finds it: a garbage bag containing rotten food and elevated levels of Strontium 90—the signature of radioactive fruit flies. With a whoop, she reaches for the bag and calls it in. "Got one," she says over the radio.

I imagine this scene as I sit at Tracy's kitchen table, sipping cherry tea and listening to her tell stories about biological vector control.[68] Tracy is a Health Physics Technician (HPT) at the Hanford Nuclear Reservation, where she has worked for twenty-three years. Also known as Radiological Control Technicians, HPTs are the border guards of nuclear industry—surveying land, equipment, and people for elevated levels of radioactivity, patrolling the official boundary between safe and unsafe exposure.

At Hanford, Health Physics Technicians are charged with containing nuclear materials, ensuring that contamination does not move beyond "controlled"[69] areas of the site. Workers, for example, must be "released" by an HPT before they can leave radioactive space, shedding protective gear like toxic skin in preparation for their return to the "uncontaminated" world. However, the scale and ubiquity of Hanford's toxicity disrupt the rigid boundaries that HPTs so faithfully enforce. Hanford's living environment, dynamic and mobile, regularly carries contamination beyond controlled territory, necessitating a multi-million dollar biological vector control program in the service of radioactive "pest management" (Dirkes et. al. 1998: 3.38).

During her long tenure at Hanford, Tracy has often been assigned vector control duty. With a wink and a reference to Spiderman, she recalls the black widow she found living in a high-level nuclear waste tank, and the day she realized that contaminated coyote urine was to blame for Hanford's radioactive telephone poles. She tells me about the atomic tumbleweeds that drink contaminated groundwater and then roll away with their toxic burden, and the radioactive mice

[68] Personal Interview. Benton County, Washington. April 17, 2012.

[69] A "controlled" area at Hanford is one in which contamination is known to exist, and is officially monitored.

and rabbits who spread Cesium-laced[70] droppings across vast areas of the site. She describes the mud dauber wasps that build radioactive nests in the eaves of aging reactor buildings and the ants that construct contaminated colonies in delicate networks underground; the herds of elk that browse irradiated grasses, spindly-legged calves in tow—their muscular bodies so infused with the bomb, they have become living breathing archives of atomic history (Image 23).

23. Biological vectors at Hanford. (Johnson and Elsen 2010).

In 2000, more than half of these irradiated lands renounced their official designation as nuclear production zone, assuming the new title and status of national wildlife refuge (undoubtedly a promotion). Created by presidential decree, these 195,000 acres now comprise the Hanford Reach National Monument: a breathtaking expanse of shrub-steppe, towering white bluffs, and 51 miles of free-flowing river, the last undammed stretch of the once mighty Columbia (Image 24).

[70] Like, Strontium 90, Cesium-137 is a common environmental toxicant found in nuclear production areas. Cesium-137 is water soluble and mimics Potassium in the body, most often lodging in muscle tissues and to a lesser extent, in bone.

24. The Hanford Reach of the Columbia River. (Photo by author 2012).

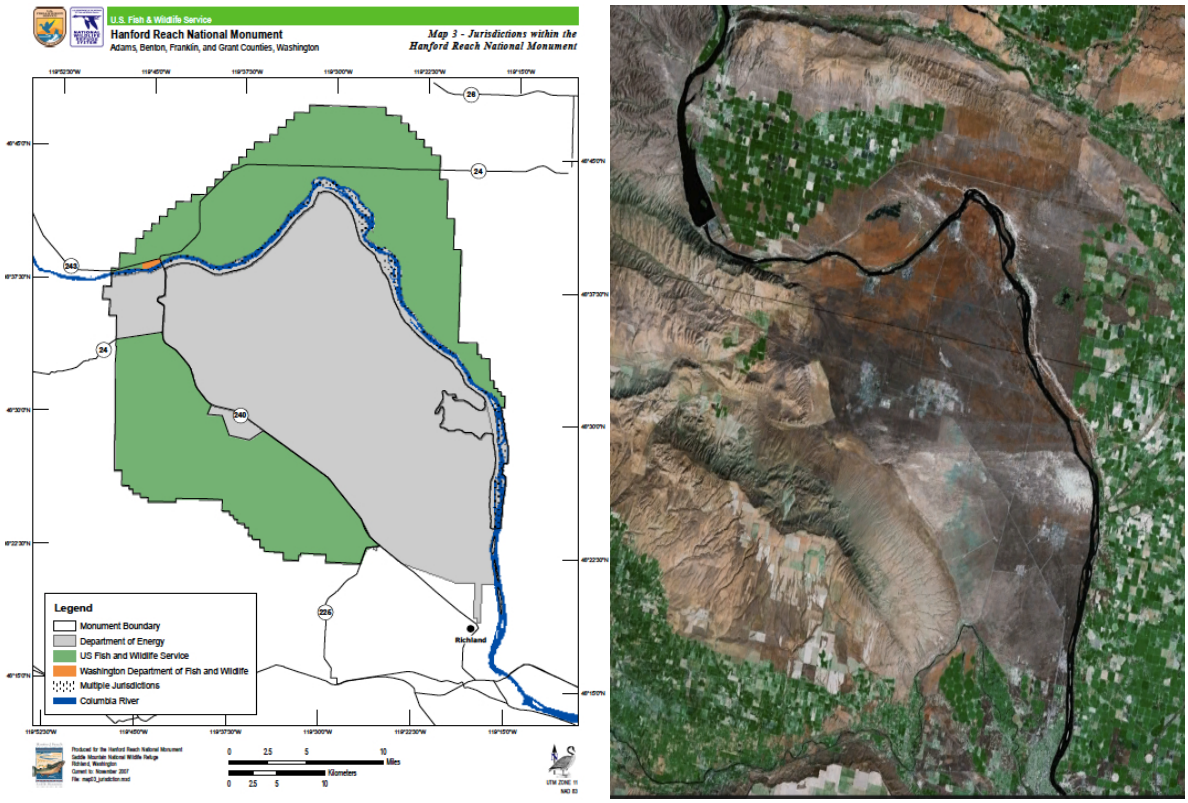
Wrapped like a thick blanket around Hanford's shoulders, the Monument rests on what was once the site's buffer zone: the requisite environmental barrier between nuclear weapons production and surrounding residential communities. Because its status as buffer offered protection from the last seven decades of agricultural and suburban expansion, the Monument now represents a unique parcel of open space in an increasingly developed region. This island of wilderness houses a diverse collection of plants and animals, including over 800 species considered rare, threatened, endangered, and/or new to science (Gerber 2007). The majority of the Columbia River's fall Chinook salmon spawn here (USFWS 2015a). It is a genuinely beautiful place. It is also home to one of the most contaminated places on Earth.

What are we to make of this wild and scenic wasteland? How can Hanford's environment simultaneously embody ruin and redemption, and what work does this constitutive contradiction do? In this chapter, I explore the slippery subjectivities of nuclear waste and nature. Beginning with the Hanford Reach National Monument, I examine how this space is positioned as both pristine habitat and waste frontier. Next, I consider how Hanford's biological vector control program addresses the spread of radioactive flora and fauna. Looking specifically at one of the site's most notorious offenders (the fruit fly), I discuss how vector control uses instances of nuclear trespass to articulate the boundary between contaminated and uncontaminated. Finally, by examining the dual production of nature as both untouched wilderness and biological vector, I consider how this slippage between pure and polluted, wild and controlled, has been employed in

the service of nuclear industry. I argue that in its doubling, nature is being recruited to do what the Department of Energy cannot: to solve Hanford's nuclear waste problem.

"THANK GOD IT'S A NUCLEAR REACTOR!"

One of the uncomfortable ironies of the American nuclear project is that daily human traffic is more immediately harmful to the environment than radioactive materials. Indeed, nuclear weapons production actually *preserved* (at least in the short term) vast ecosystems that would have otherwise been lost to agricultural and suburban expansion. It created a unique cartography of irradiated open space—large areas of land whose military fortifications produced a national map of toxic un-development (Image 25).



25. This 2008 USFWS map shows the boundaries of the Hanford Reach National Monument in green (the rest of the Hanford site is grey). In the corresponding image (taken from Google Earth), note the visual distinction between the irrigated suburban and agricultural land and Hanford's arid landscape.

The Hanford Reach National Monument, for example, boasts the largest parcel of shrub-steppe vegetation in Washington State. As Geographer Morris Uebelacker describes in the 2007 documentary *Arid Lands,*

> That landscape of irony really struck me one time when I had to survey a power line out by the Fast Flux power reactor [at Hanford]…The first thing I noticed is that this might be the first time I was ever in shrub-steppe vegetation that looks like its supposed to out of a text book. And I realized that by being internal to Hanford, and keeping people out, they had actually created pockets of vegetation that were healthy. I mean this blew me away! I thought, my god! So I started to say things like, well *thank god it's a nuclear reactor* or we wouldn't even know what shrub-steppe vegetation ought to look like!

Within this logic, preservation is a natural byproduct of the atomic age. Weapons production not only saved American citizens from Soviet attack, but it also rescued critical habitats from the ravages of development. Nuclear wildlife refuges, therefore, allow the Department of Energy to "expand retroactively its Cold War mission from nuclear deterrence to environmental protection…replacing nuclear weapons systems with biodiversity as the security object of the nuclear state" (Masco 2006: 313). So too, this strategic emphasis on "returning to nature" envisions the nuclear project as having come full circle, equating the pre-nuclear past with the post-nuclear future.

This transposition of land from production to preservation permits the U.S. government to complete the atomic cycle both discursively and bureaucratically. Over the last fifteen years, the Department of Energy and Department of Defense have transferred hundreds of thousands of acres into the hands of the U.S. Fish and Wildlife Service (Havlick 2014, 2011, 2007). This administrative code-switch—alternately referred to as military-to-wildlife, warfare-to-wildlife, and bombs-to-birds—imagines a clean break between human and non-human worlds. It evokes preservationist notions of nature as healer, fundamentally adaptive once free from the destructive human, nature's other. Radioactive ecologies thus serve as evidence of survival rather than destruction. Plants and animals become proof of post-nuclear perseverance, "emblems of nature's resilience as opposed to its vulnerability, porosity, or damage" (Krupar 2013).

Visitors to the Hanford Reach National Monument website, for example, are greeted with the following description:

> The Monument is a place of sweeping vistas and stark beauty, of towering bluffs and delicate flowers. Wildlife abounds in this harsh landscape—rare is a trip along the river that doesn't produce mule deer, coyotes, bald eagles, great blue herons, or white pelicans. A large elk herd hides in the canyons, and incredibly, porcupines are a common sight. Rare plants defy the drought, wind and heat…So, whether you're interested in history, sightseeing, wildlife, hunting, fishing, or just enjoying a bit of time away from the bustle of everyday life, the Hanford Reach National Monument has something to offer you. But don't come expecting a lot of visitor facilities—they don't exist. You'll be experiencing the Monument on its own terms (USFWS 2015b).

The Monument in this frame is an active space, housing a community of natural survivors. Its rare plants don't simply exist in Hanford's arid environment, they "defy the drought, wind, and heat." A picture of autonomy and self-determination, the Monument evokes the transformative potential of Turner's frontier, successfully negotiating the "harsh landscapes" of western aridity and nuclear contamination "on its own terms." The Monument's website therefore espouses a basic logic of the weapons-to-wildlife program: nature, if left to its own devices, can survive

nuclear disaster. Amazingly, this narrative transforms Hanford—the most toxic nuclear site in the Western Hemisphere—into an environmental success story. The solution to nuclear contamination, it seems, is to simply let nature be.

Of course, these redemption stories rely upon a selective view of nuclear transformation. Privileging external metrics for ecological health, they elide the cellular transgressions and mutant potentialities that also distinguish these parcels of uncommon Eden. Exposure produces disparate effects, each body a distinct expression of nuclear contact.[71] So too, radiogenic illness, especially in the case of low-level exposures, may take decades or even generations to manifest. These extended timescales remove the element of immediate causality, introducing doubt as to the source of cancer, mutation, and birth defects. Thus, contamination's impact often exists at the level of partial knowledge—a collection of symptoms and stories, aches and pains, that remain fractured beneath Medicine's totalizing gaze (Petryna 2002; Murphy 2006; Alaimo 2010).

The creation of places like the Hanford Reach National Monument is a critical component of this uncertainty management. Placing the emphasis on salvation rather than contamination, the DOE positions itself as caretaker of fragile ecosystems, protector of a pre-industrial past. At the same time, it forwards claims about possibilities for the post-nuclear future—of landscapes returned, good as new, to the communities who participated in the U.S. nuclear endeavor. As Washington senator Patty Murray said of the Monument's designation in 2000,

> I'm thrilled this day has finally arrived, that the Hanford Reach will be protected for generations to come. This designation means more salmon restoration, more recreation and tourism, and national prominence for the Tri-Cities community and the state of Washington. My dad grew up in the Tri-Cities. When I started fighting to protect the Reach, he told me how proud he was that I was working to give something back to a community that has given so much to our family and our country.

In her speech, senator Murray uses the spectacle of environmental preservation to rhetorically manage the multi-millennial challenge of nuclear waste. The "generations to come" she imagines enjoy eternal nature in the form of wildlife rather than radionuclides.

What senator Murray fails to acknowledge is that the Monument's designation "gives something back" to the Department of Energy as well. Because remediation must adhere to human-based risk standards under the terms of federal law, re-inscribing nuclear space as natural space means that less material nuclear management is necessary. Humans are not allowed to live in national wildlife refuges, which dramatically reduces the risk that they will develop cancer from these places. Therefore, the Department of Energy can leave *more* radioactive waste in the environment while still remaining legally compliant. The refuge designation thus operates as a

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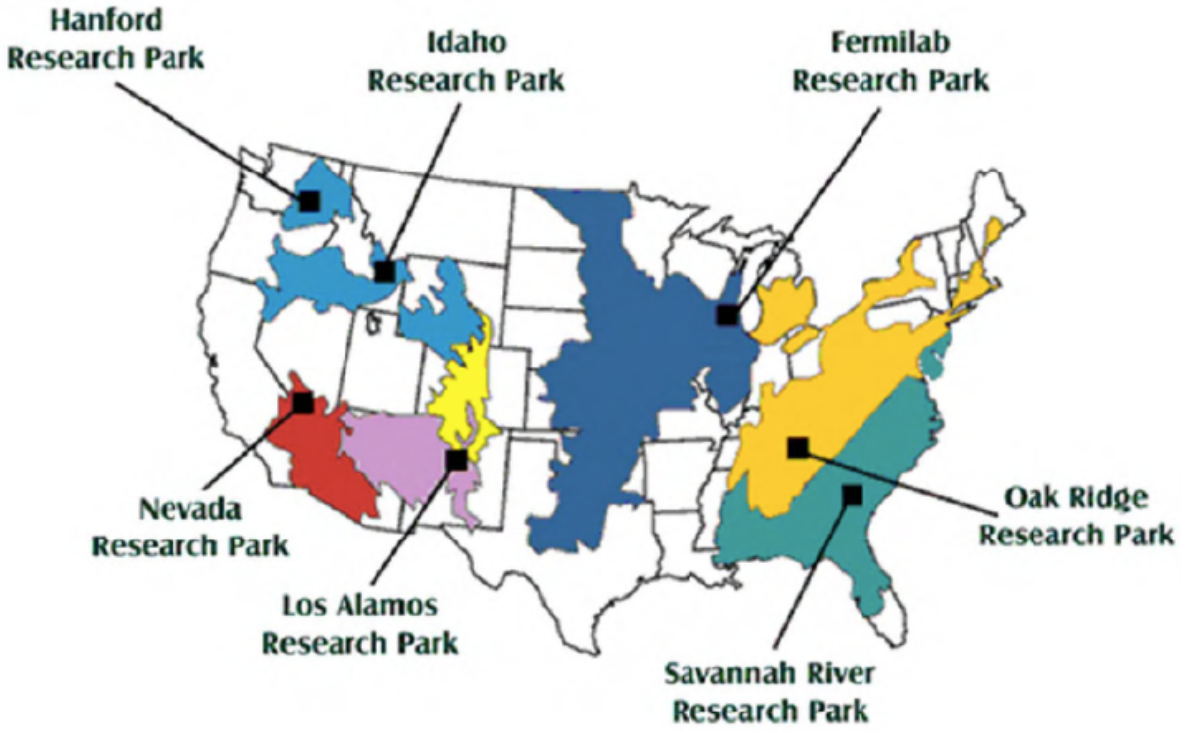
[71] Early (1940s) studies with mice showed a diversity of responses to radiation. According to a Columbia University study, the "mice lost weight, hair, and white blood cells. They became anemic, grew sterile, and developed cataracts. Their lungs became inflamed and clouded with bacteria. Strangely, the mice suffered these symptoms in different ways, no two alike. After 34 weeks most of the mice had died. On autopsy, the doctors could not determine a specific cause of death—not a tumor, a cancer, or organ failure—and attributed death to a 'general malfunctioning." (Brown 2013: 58).

form of "thrifty environmentalism" (Iversen 2012)—one that "preserves" federal expenditures as well.

This doubled nature is also evident in the Monument's official role as natural laboratory. Hanford maintains one of the Department of Energy's seven National Environmental Research Parks (NERPs): multi-use outdoor laboratories that examine the ecological dynamics of nuclear production. Initiated in 1972 with its first research park at the Savannah River site, the NERP program emerged in response to new federal mandates that industry evaluate its environmental impact. Though weapons production often eluded such environmental requirements, NERPs provided opportunities for expanding the methodological boundaries of fields like radioecology. The program has continued to expand both scientifically and geographically and now comprises more than two million acres of land (Pava 2011) (Image 26).



26. The National Environmental Research Parks system. Colored areas indicate associated eco-regions rather than the boundaries of the parks themselves. Nevada maintains the largest NERP at 865,000 acres followed by Idaho (568,000 acres), Hanford (366,000 acres), Savannah river (198,000 acres), Los Alamos (25,6000 acres), Oak Ridge (21,500 acres), and Fermilab 6,800 acres) (Pava 2011).

Weapons production and environmental science have long been productively entwined (Hamblin 2013). During the Cold War, for example, questions about nuclear fallout produced an unprecedented commitment to research in climatology and the earth sciences (Masco 2009, 2014). Likewise, the field of ecology expanded in step with the international arms race, as radioactive materials from weapons testing allowed scientists to track ecosystem flows and dynamics (Kosek 2006; Kuletz 1998). As Howard and Eugene Odum wrote in their

foundational text *Fundamentals of Ecology*, "Some of the things which we fear most in the future, radioactivity, for example, if intelligently studied, help solve the very problems they create. Thus, isotopes used as tracers in the environment elucidate turnover processes which we must understand before radioactive waste materials can safely be released into the environment" (1959: v-vi).

The NERP program reflects this tautological reasoning that contamination can be both problem and solution. "Serving important national defense, science, engineering, and industrial purposes," Shearer and Frazer write, "NERPs also have a complementary role conducting research on environmental impacts…protecting important habitats, and enhancing remediation and restoration technology" (1997: 46). In this sense, they argue, NERPs reflect the broader "complementarity principle" that atomic weapons "are at once the means of man's destruction and of his salvation" (ibid). Representational spaces like the Hanford Reach National Monument are thus used to naturalize the logic of nuclear deterrence. By symbolizing survival (even resilience) in its radioactive state, the Monument embodies the constitutive contradiction of Mutually Assured Destruction—that technologies of war engender peace.

THE ATOM AND THE FLY

The atomic wildlife refuge only retains this strategic utility, however, if nuclear waste stays in the nuclear wilderness. Thus, the Department of Energy has instituted an extensive biological vector control program to maintain the discursive integrity of nuclear space. Established in 1999, Hanford's Integrated Biological Control (IBC) system was designed to "reduce or eliminate spread of radioactive contamination by biotic vectors" (Johnson et. al. 2010). Since its inception, IBC has identified 81 biological vectors on site (30 species of vegetation and 51 species of wildlife) and documented approximately 5,400 instances of "biological intrusion" (ibid).

Though the current IBC program has been operating for less than two decades, the DOE has been monitoring its radioactive flora and fauna for much longer. Hanford scientists wrote the site's first official ecological monitoring report in 1947, detailing the presence of nuclear materials in bird populations. Throughout the following decades, Hanford produced many subsequent reviews, formalizing the "environmental surveillance" process through annual reports beginning in 1965. Translating irradiated livers, bones, thyroids, and testes into sanitized ledgers, these reports make for an unsettling read. In each, animal bodies are deconstructed and rendered quantitative, creating tidy spreadsheets of ecological impact (Image 27).

In the post-Cold War era, ecological monitoring at Hanford has expanded from producing classified technical reports to serving the DOE's "communication needs" as well (Johnson et. al 2010: 2). As Mission Support Alliance (the private contractor that runs Hanford's IBC program) notes, "Interest in radioactive contamination spread has increased over the years from being localized to technical specialists on site, to making national and international news. Today, communication is to a variety of customers," including members of the public and the media (ibid). Thus, the IBC system is explicitly designed to manage the spread of both biological vectors and information, providing its "customers" with messages of containment and control.

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Location	Direction and Distance from 200 Areas	Type of Fowl	Date	Thyroid	Bone	Testes	Liver	Kidney	Muscle	Gut
(8 Mi. SW) Benton City	15 Mi. S.	Pheasant	10/12/47	~ 40	< 3	< 100	<10	< 7	< 6	~8
Benton City	15 Mi. S.	Pheasant	10/18/47	< 60	<5	< 40	<5	~ 4	<5	~3
Benton City	15 Mi. S.	Pheasant	10/19/47	300	<6	< 80	<3	< 5	<6	<5
½ Mi. W. Benton City	15 Mi. S.	Pheasant	10/12/47	-	12	-	<3	< 8	<3	9
1½ Mi. W.W. Benton City	15 Mi. S.	Pheasant	10/12/47	1300	< 2	< 50	<7	< 10	< 8	~4
3 Mi. E. Benton City	15 Mi. S.S.E.	Pheasant	10/12/47	820	< 6	<40	<5	< 6	< 6	<5
3 Mi. W. Richland	15 Mi. S.S.E.	Quail	10/12/47	3600	-	-	< 9	-	<6	5.2
3 Mi. N.W. Richland	15 Mi. S.S.E.	Pheasant	10/16/47	1400	< 3	< 60	<3	< 4	<6	<5
3 Mi. N.W. Richland	15 Mi. S.S.E.	Pheasant	10/12/47	5000	<4	< 20	~9	< 3	<8	5.7

27. Partial list of radioactive pheasant and quail data (Herde 1948).

Hanford's current IBC program[72] was instituted following the now-famous "fruit fly incident" of 1998. The incident, which began with a set of mysterious circumstances, brought a flurry of media attention to the site. On September 28 of that year, Health Physics Technicians surveying a mobile office trailer that was being used as a lunchroom[73] noticed an unusual pattern of contamination. Radioactive material on the light switch, knife, and cutting board initially led HPTs to believe that the source was someone's contaminated hand. However, the distribution of radioactivity was strange, registering on the tip of the knife but not the handle. A few minutes later, HPTs found radioactive chewing tobacco in the trailer's garbage bin and it seemed likely that this person had been internally contaminated.

When a Hanford worker identified a pair of contaminated socks in their home later that evening, the individual in question seemed to have been found. Subsequent bioassays of the worker's urine, however, did not show elevated levels of radioactivity (DOE 1999). Instead, the source of the contamination was identified the following day when an HPT surveying the same trailer noticed a speck of contamination "fly away" (Dirkes et. al. 1999). Perplexed, she called her partner over and together they repeated the exercise with the same result. Further investigation revealed that fruit flies—a previously unidentified vector at Hanford—were to blame.[74]

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[72] Which replaced its previous Integrated Pest Control System (talk about what changed specifically in this update). Contractor also changed from Flour Daniels Hanford to Mission Support Alliance.

[73] The mobile office trailer is formally called MO-967, which can be seen in Image 28 below.

[74] There is a subtle irony in the fact that a fruit fly inspired Hanford's new system of Integrated Biological Control. In 1927, a fruit fly also provided the first scientific evidence of radiation-induced mutation. According to Dr. Hermann Muller, who won a Nobel Prize for his studies in 1946, any dose of ionizing radiation can produce a genetic effect. However, this effect—while still harmful in a multi-generational sense—will not usually be immediately obvious. Muller was frustrated by cinematic representations of radiogenic monsters like the giant ants in the 1954 film *Them!* "The popular idea that a mutation ordinarily results in a monster or a freak is a gross distortion of the facts," he wrote in 1958 (232). This

In the weeks that followed, multiple hypotheses were put forward as to the source of the fruit flies' radioactivity. Ultimately, the DOE concluded that the flies had been drawn to a monosaccharide-based fixative that had recently been sprayed in one of Hanford's diversion pits. Laying their eggs in the sugary sweet waste, the flies' babies were born radioactive. When the young left home, they spread contamination to a variety of areas including the trailer lunchroom and bathroom, the Ironworker shop, the Canister Storage Building, the clothing of at least three workers, several dumpsters, and eventually the city dump via routine garbage collection.

Evoking the plot of the popular 1954 horror film *Them!*, Hanford's fruit flies made for easy headlines. The local Tri-City Herald published its first article after an anonymous tip, and the story was quickly picked up by news outlets across the country. Subsequent headlines mark the progression of the event: "Radioactive socks found in Hanford worker's home" (1998); "Hanford puzzled by radioactive garbage bin" (Stang 1998a); "Fruit flies suspects in Hanford's contamination" (Cary 1998); "Hanford works to trap contaminated bugs" (Stang 1998b), and so on.

Hanford management leapt into action, struggling to contain both the fruit flies and the message that their nuclear escape was sending. The DOE established a situation room near downtown Richland dedicated to the response effort, complete with a system of "integrated sub-teams" for addressing issues like radiological control, solid waste, and policy (DOE 1999: F-6, F-7). Fly traps were installed across the site, affected areas sprayed with the insecticide Malathion, and a ten-acre radiological buffer created around the mobile office trailer and diversion pit area. More than 100 workers provided urine for bioassay testing. HPTs (including Tracy) were sent to the city landfill where they spent weeks surveying mountains of trash. In the end, more than 200 tons of garbage were returned to the Hanford site and placed in low level nuclear waste burial grounds. The entire incident cost the DOE about two million dollars (DOE 1999: I-3).

However, despite its rigorous, expensive, and very public response, the DOE maintained that the fruit flies had never presented a risk to human health or the environment. As vice president of environmental health, safety, and quality Bob Shoup explained, most of the flies registered radioactivity rates of about 20,000 disintegrations per minute (dpm)—a little less than a dental X-ray.[75] Nevertheless, Shoup reiterated in multiple public announcements, "we have zero tolerance for any contamination spreads" (Gerber 1998). In a site-wide message to Hanford employees, he wrote, "Any contamination outside of a control zone is of concern *because it isn't supposed to happen*…Even though the level of contamination is very small, any contamination outside of controlled radiation areas is unacceptable" (DOE 1999, italics added).

Shoup makes it clear, therefore, that the DOE's multi-million dollar response had more to do with the sanctity of the boundary than the fruit flies themselves. While their escape pointed to the inherent "slipperiness" of nuclear waste, the flies also allowed the DOE to emphasize tactical divisions between contaminated and uncontaminated space. The spectacle of the search for atomic fruit flies pointed to the porosity of Hanford's border while at the same time reproducing

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misconception, he argued, allows people to ignore the risk of smaller genetic impacts that grow increasingly harmful with time.

[75] Several flies registered higher dpm counts, reaching close to 1,000,000 dpm.

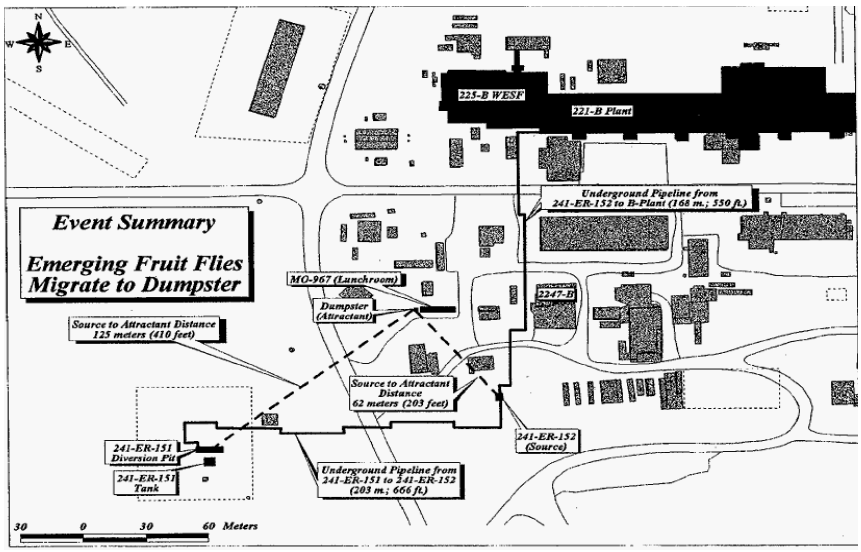
that border as the official boundary that nuclear materials are "not supposed to" cross within normal operating procedure.

Thus, the fruit flies functioned as a proxy for radiation itself. Invisible and elusive, radioactivity evades physical and explanatory capture, making it extremely difficult to manage. As John Wirth, medical director for Oak Ridge wrote in 1951, "[Radioactivity] seems to get about as though it were a living creature, trying to spread itself anywhere" (32). Indeed, the tiny size of each individual fruit fly, and the fact that it could land on something quickly and leave its mark without being seen, made it easy to equate the two.

Published in one of many official site-wide messages, workers' questions about the event speak to the physical and psychological challenge of negotiating this invisible hazard. Among many other things, workers asked:

- How can I be sure that I'm not transporting contamination home?
- There was enough contamination to shut down the Canister Storage Building on Wednesday. Why are we not concerned about working there today (Thursday)?
- If contamination is not a big concern, then why are there so many news stories (i.e. newspaper articles and TV news)?
- The contaminated fruit flies have been detected in the 200 Area. How far can a fruit fly fly? (DOE 1999).

In apprehending every single tiny fly, drawing detailed maps of their movement (Image 28) and sending workers to pick through tons of city garbage, the DOE sought to communicate the broader message that nuclear containment is possible. It positioned the flies' escape as an accident, an aberration that could be prevented through procedural modifications and increased surveillance. Thus, vector control was not just managing fruit flies, but the ambiguous nature of radioactivity as well.



28. Diagram of the fruit fly incident (DOE 1999).

Several months after the fruit fly incident officially came to a close, the DOE published the "Fall 1998 200 East Area Biological Vector Contamination Report." Containing 229 pages of diagrams, summaries, and analyses, the report determined that while the "direct cause" of the incident was fruit flies, the "root cause" was a larger problem of "inadequate process" (4-1). In response, the DOE initiated the Integrated Biological Control program to improve the security of Hanford's radiological areas.

Based on "new policies and procedures to unify the control of biota" (Johnson et. al. 2000: 2), IBC is a distinctly biopolitical project (Foucault 2004). It extends disciplinary logics to non-human subjects, positioning nature as integral to the management of nuclear life. Under this new program, contaminated plants and animals are critical to the administration of Cold War remains. Through public displays of border crossing and capture, biological vectors transform invisible and insensible radioactivity into a visible, tangible enemy that can be contained.[76] Integrated Biological Control, therefore, allows the DOE to defend its nuclear border against the ambiguous and unseen, an action that is critical to cleanup's social production.

CONCLUSION

When Tracy finishes her story about the fruit fly incident, she remembers that she has something she wants to show me. "I'll be right back," she says and goes down the hallway to her bedroom while I reach for another homemade muffin. Her dog who has been sitting next to me for several hours, lays his head in my lap and looks at the muffin hopefully.

When she returns a few minutes later, Tracy is holding three old T-shirts. "I found them!" she says triumphantly, holding them up one by one for me to see. The first features a manic-looking cartoon fly, glowing with radioactivity. The shirt reads, "Frutonium-98" as if the fly is evidence of a new element on the periodic table.[77] "The workers on the fruit fly crew made these," she says chuckling. "98 is for the year that it happened."

The second T-shirt has a drawing of HPTs laughing in disbelief beneath the words "You want me to release *that?!?*" Large cartoon tears spring from their eyes at the hilarity of this absurd directive from management. In its irreverence, the shirt points to the political nature of nuclear safety at Hanford. The HPTs are laughing because the idea of releasing an obviously contaminated item is irrational, ridiculous in the extreme. However, the shirt is only funny because it also recalls something familiar: they have each been in this situation before.

The final T-shirt is simple—no images, just words: "HPTs don't get old, they're just re-characterized." We laugh for awhile when Tracy shows me this one, appreciating its mix of sarcasm and nuclear jargon. Characterization is the process of testing and categorizing nuclear waste based on its relative radioactivity and origin. It is a complex process that lends itself to political manipulation (there is an incentive to characterize material economically). Joking that HPTs could be re-characterized not only references the plasticity of the category, it also equates working bodies with nuclear material, linking waste and worker in their shared radioactivity and

[76] As management told Hanford workers during the fruit fly incident, "You are on the front lines" (1999).
[77] Hanford was in the business of making Plutonium-239.

disposability. Like the T-shirt before, it's the kind of funny that makes you roll your eyes knowingly because you recognize the dysfunction it implies. It's funny-sad, funny-exasperated, funny-ironic.

Tracy's stories and the others I have told in this chapter speak to a broader politics of nature in the atomic age. They narrate a world that has been fundamentally altered by the bomb, producing new categories of meaning and matter (Frutonium!). Nuclear production, in other words, has changed the very "nature" of nature, disrupting taken-for-granted divisions between subject and object. It has transformed relationships between society, environment, and self and has even challenged the basis for these terms.

Remediation at Hanford represents a struggle over these new material-discursive categories. At stake are the conditions of nuclear impact—the meaning of "clean" on a planet saturated with fallout, the meaning of "injury" when mutation is the norm. As Gabrielle Hecht has argued, even "nuclear" is up for debate. "The boundary between nuclear and non-nuclear has been frequently contested," she writes. "The qualities that make a nation, a program, a technology, a material, or a workplace count as 'nuclear' remain unstable, even today" (2012: 14). This points to a social and administrative challenge that I have explored throughout this dissertation: how can one structure and implement nuclear cleanup when the definition of people, spaces, and materials in question are fluid and changing, even contradictory?

In this chapter, I have explored the multiple and often paradoxical natures that have emerged out of this search for definition. Creating the conditions of remediation has meant positioning nature as both healer and vector, wilderness and waste, ruined and redeemed. Indeed, this ability to tack back and forth allows the category of nature to play to structures of power. Its meaning depends upon particular histories and geographies, bodies and politics, nations and nationalisms. Thus, Hanford's nuclear natures matter in an ontological sense, but also in the conditions of their making. They embody the intricate social relations and uneven suffering constitutive of the plutonium economy.

In *Understories,* Jake Kosek writes, "the weakness at the heart of environmental politics is that it does not take seriously the politics of nature" (2006: 273). With this in mind, I have sought to "expand the terrain" on which we understand the nature of nuclear politics (274). By exploring the ways that wilderness and vector have become paradoxically and productively entwined, I am speaking to the larger social project of remediation at Hanford. I argue that by calling upon nature to mark the territories of both injury and recovery, remediation seeks to reimagine the scale and consequence of atomic development.

Reproducing the official dimensions of controlled space through the imagination of its outside is vital to "closing the circle" of nuclear production. It maintains the notion that there *is* an outside to nuclear contamination, that Cold War sacrifice zones have bounds. These narratives of containment have been naturalized through the Hanford Reach National Monument, the National Environmental Research Park system, and the Integrated Biological Control program. In each, nature is used to rethink the post-nuclear future—transforming nuclear wastelands into manageable, aesthetically potent, scientifically productive, and economically efficient spaces.

CONCLUSION

On a Tuesday morning in late February 2012, I rose early to drive from Seattle to Olympia, Washington. The sky was soft with its familiar blanket of clouds and the staccato rhythm of rain filled my car. I was heading to Olympia for a day of interviews with several former Washington State employees. Working for the state's Department of Ecology in the 1980s and 90s, these men had helped design the legal framework for remediation at Hanford more than two decades before.

I had been looking forward to these interviews for weeks, and the day did not disappoint.[78] Strange as it is to say, the legal wrangling of policy development can make for a gripping story! As we sat around the board room table in a non-descript office building, the early moments of Hanford's cleanup came to life. I could feel the suspense as they described waiting for news from an informant, could imagine their quick pace as they rushed to a secret meeting ("very cloak and dagger stuff," one of them said). We laughed sardonically at the moment when the Department of Energy officially admitted it had waste problem and rolled our eyes at the glacial pace of bureaucratic process. We discussed the ambivalence of political compromise, the second guessing that accompanies decision-making, and the discordant pairing of triumph and defeat that each felt when the cleanup agreement was signed.

Finally, we arrived at the regulatory challenge of containing eternal waste, the surrealist task of administrating the unthinkable. One person said,

> Last week this couple asked me, 'how long is [the waste] going to be there?' and I said, 'Forever. It will be there forever.' Well, they were horrified by this idea. They said, 'But you know, where does it go then? It's just kind of swept up? You're just going to go put it somewhere?' Well, we've created these things and they don't go away. We can isolate materials from human beings and the environment. We will do that successfully, I think. I won't say that we'll be one hundred percent successful because I don't believe in one hundred percent, I think that's too hard of a metric. But you know, high nineties.

Another looked at me and said, "You're writing a dissertation, here's what I think you should write about: This is not only a test of the United States, this is a test of our species. The genie is out of the bottle, and there's no putting the genie back in. Well," he paused and pointed to an old picture of Hanford on the table in front of us, "this is the legacy of that genie. This is a test of our society. Are we really willing to do what it takes to remedy this situation?"

As I drove back to Seattle that afternoon, his question stayed with me. In fact, since our meeting, I have noticed it being asked frequently, albeit in different forms. It emerges when Hanford managers describe political gridlock and budgetary constraints, and when activist groups argue for better worker health and safety protocols. Indeed, in many ways, "are we willing to do what it takes?" is a very practical question. It invites iterations like, how much money would it take to make this cleanup project work? What kind of regulations would be necessary? And, do "we" as individuals, nations, and communities have the capacity to make it happen?

[78] These interviews took place on February 21, 2012 in Olympia, Washington.

Of course, this question also evokes a logic of care, as if remediation is simply a matter of political or social will. As such, it functions as a means for negotiating the psychosocial discomforts and rational inconsistencies of an impossible nuclear cleanup. It allows Hanford workers, activists, scientists, and policy makers to argue that if only there were bigger budgets, better technologies, and greater public interest, remediation *could* be possible. However, these same people *also* recognize the regulatory impossibilities of Hanford's waste—they acknowledge that the genie has already left the bottle, and that there is no putting it back.

How, then, can cleanup move forward? If Hanford's waste exceeds the spatial and temporal boundaries of regulation, is planning for its containment a futile endeavor? Though my intent in this dissertation is to take impossibility seriously, I am not making an argument for inaction. On the contrary, I remain deeply committed to improving how we reckon with the meaning and making of nuclear contamination. However, in this effort, I argue that improving the terms of cleanup means asking better questions. Instead of, are we willing to do what it takes, we should be asking what are the politics of our actions? What are the conditions in which remediation is designed, embodied, enacted, and understood? What social relations give these actions meaning and what does this tell us about our capacity to create positive change? For that matter, what would positive change look like? Positive for whom?

In the past few months, the need for such conversations has become increasingly urgent. As part of his recent congressional budget request, President Obama proposed a massive spending package for rebuilding the nation's nuclear arsenal. At a cost of $348 billion dollars over the next ten years and an estimated $1 trillion dollars over the next thirty (Young 2015), this plan seems to run counter to the president's explicit commitment to nuclear disarmament. However, Obama maintains that upgrading the arsenal is consistent with his mission "to achieve a nuclear-free world" (White House 2009). In fact, his administration frames this massive overhaul as critical to creating a future without nuclear weapons, saying "improvements to the nuclear arsenal are vital to making it smaller, more flexible and better able to fulfill Mr. Obama's original vision" (Broad and Sanger 2014).

Of course, the logic that having fewer, "more flexible" weapons brings the world closer to a nuclear-free future fails to recognize that disarmament is more than a question of numbers. For, if the U.S. increases the "killing power" of its warheads (Postol 2014), does it really matter that it has reduced the size of its arsenal? Furthermore, what is the utility of improved warheads in an age of cyber-terrorism and suicide bombing? Will these new weapons truly ensure national security, or will they simply reproduce the politics that give the bomb value?

Just as improving remediation means attending to the social relations of nuclear contamination, disarmament requires closer attention to the origins of nuclear threat. Achieving a nuclear-free world is not about making fewer weapons, it is about addressing the structural violence that has made the bomb politically necessary. Thus, "unmaking the bomb" requires much broader forms of critical engagement. It calls for dramatic changes in how national security and nuclear impact are officially imagined—and asks that individuals, communities, and nations reckon with the fact that this "unmaking" can never be complete.

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