2010

When Curiosity Kills More Than the Cat: The Perils of Unchecked Scientific Inquiry

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i. Introduction

> After I presented a paper on Earle Reynolds's activism […], a disgruntled reporter from *Newsday* objected to my description of Reynolds the activist as a scientist in good standing. The reporter insisted that scientists who become involved in political advocacy forfeit their standing as scientists because they have abandoned their commitment to neutrality- a hallmark of scientific observations. In replying to the reporter, […] a senior mathematician from Yale stood and told (him) that the hallmarks of science were not found in political neutrality. Instead, they were measured by whether or not the observations, measurements and theories provided […] had high reliability and validity. […] She added that being a scientist did not remove anyone from the responsibilities of citizenship. […] Reynolds understood that there are public duties embedded in scientific knowledge and that science without consideration of the public good is folly.
>
> -David Price, 2007

With more than ninety vessels floating in its vast, blue lagoon on the morning of July 1st, 1946, Bikini Atoll was the epitome of tropical paradise. Cleared of its inhabitants who had been evacuated earlier that year, the island was quiet. All of this would change within hours when Able, a 23-kiloton atomic bomb, detonated just 520 feet above ground. Able set into motion not only a powerful chain reaction within but a sequence of events with dire environmental, health and social consequences not just Bikini Atoll, but the entire nation of the Marshall Islands (Figure 1).

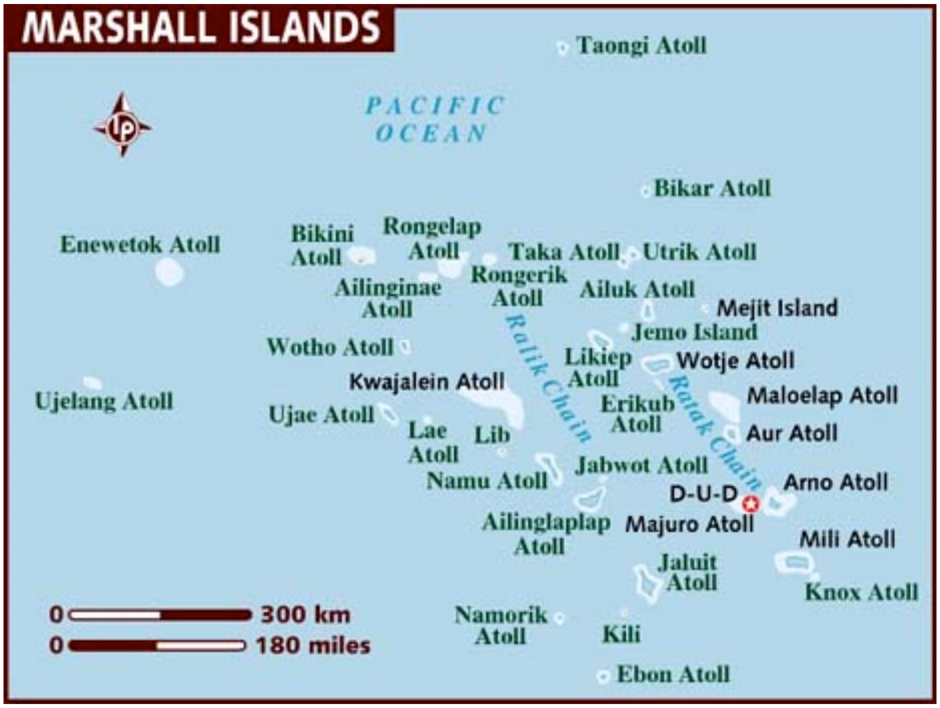

Figure 1. Map of the Marshall Islands. (Lonely Planet)

Able was the first of two explosions in a test sequence dubbed Operations Crossroads. In advance of these twin explosions, codenamed Able and Baker, the U.S. government had evacuated the population of Bikini Atoll in March, 1946. Able was followed closely on July 25th by Baker, an underwater detonation in the lagoon. Although the island's residents were absent, ships anchored in the lagoon were loaded with goats, pigs and other livestock to see how they would fare in a nuclear attack. In addition, U.S. soldiers were sent in after the detonation to survey and clean the surviving ships, all receiving dangerous doses of radiation in the process. These soldiers were not the only victims contaminated by Able's radioactive blast. The entirety of Bikini Atoll was covered in a blanket of radiation that remains today, continuing to make the island uninhabitable. As if these blasts were not devastating enough, there were plenty more to come. The U.S. government had found what it believed to be the perfect location to expand its nuclear testing program: Pacific territories that were isolated and far from home. Between 1946 and 1958, the United States performed 65 additional nuclear tests in the Marshall Islands, with

each detonation increasing the amount of dangerous radiation exposure to unwitting island communities (Barker, "Half-Lives" 214). With or without their consent, the Marshall Islands were not only inducted into the Nuclear Age, but they had become its glowing epicenter.

I knew none of this history when I began to think about my senior thesis in May 2010. This was certainly not the thesis that I intended to write. My original project was to be a continuation of research I had undertaken at the University of Auckland while studying abroad in New Zealand. Centered on water-quality testing of the Tarawera River downstream of a large pulp and paper mill, the logistical complications of international sample transport proved too great to continue this project back at Pomona. As I result, I was forced to find a new topic. I hastily agreed to a project analyzing soil samples at the Bernard Field Station (BFS), north of the Claremont Colleges, a worthy project, but I knew that my true interest lay beyond the confines of the 5Cs.

After my semester abroad, I spent six weeks in Rarotonga, a small South Pacific island, and developed a keen interest in the region. Intrigued by the variety of challenges facing these small island nations due to their unique environment, when my advisor, the ever-wise Rick Hazlett, mentioned the nuclear testing in the South Pacific, I jumped at the idea of studying this part of the world further. Scrapping the BFS soil testing, I instead chose to focus my research on the Republic of the Marshall Islands, another South Pacific nation, consisting of twenty nine atolls and five islands, located west of the international dateline (see Figure 2).

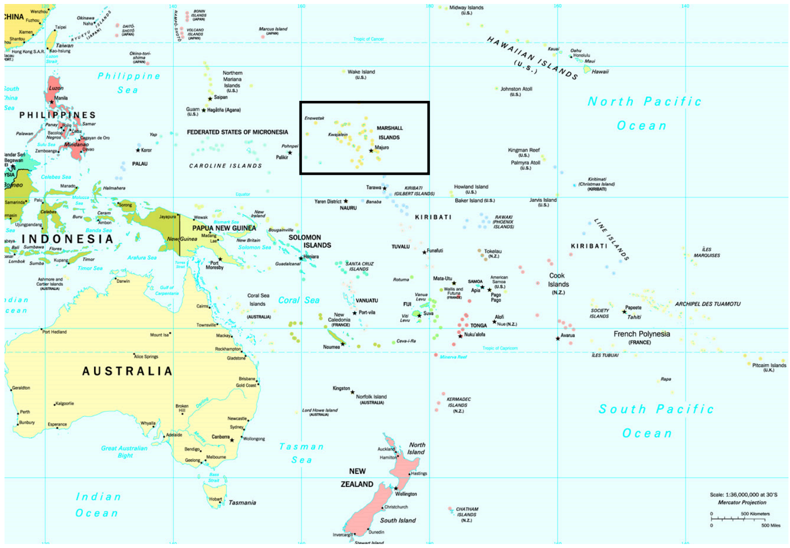

Figure 2. Map of the South Pacific. The Marshall Islands are designated by the black box. (mapsof.net)

The atrocities that the U. S. committed here as part of our extensive nuclear testing program during the Cold War have created a hideous legacy of chemical contamination, significant health problems, and social fragmentation that continues to reverberate throughout Marshallese society today. I hope that this thesis will highlight not only the chemical and biological impact of the testing, but also how the alteration of the natural environment has had a very profound and lasting effect on the Marshallese people.

While I initially set out with an eye towards the marine environment and how it was impacted by the nuclear testing, I soon realized that this was far too narrow an approach and frankly not all that interesting without answering *why* it happened in addition to *what* had happened. I also realized that the answer to this question was somewhat irrelevant without addressing a complementary query: what impact do changes in the physical environment have on the human environment? This connection between the physical and human environment is not a one-way street. Furthermore, these are not the only two terms of the equation. In my initial inquiry, there was little room for public policy or politics to play a part. Sure, it's easy to vilify the policy makers who decided to turn the Marshall Islands into an American nuclear

playground, but this is not a fair assessment without considering of the state of the world in the mid-20th century. What happened in the Marshall Islands is inextricably tied to the Cold War atmosphere of the day. I also had trouble with laying all the blame on politicians, who were by no means the only ones making decisions regarding the nuclear test program. What about the scientists and researchers involved in each step of the process? What role did they play? Here I found myself in a bit of a frenzy. The very project that I had sought to simplify by focusing on the marine environment stubbornly expanded back to its original size, with even more questions.

Resigning myself to, or *embracing*, the complexity of this project, I decided I needed a different approach, one that did not confine my research to only a narrow sliver of information deemed relevant for the sake of simplicity (or my, the researcher's, sanity). Tackling this project from a broader, interdisciplinary perspective is much more in line with the methods I learned while studying abroad. My semester program in New Zealand placed a strong emphasis on the interconnectivity of field and laboratory science with social, cultural and economic issues. It is this multi-disciplinary approach that drew me to Environmental Analysis in the first place. Michael Polanyi, a Hungarian chemist and philosopher who theorized extensively on the philosophy of science, offers a useful analogy. Comparing jigsaw puzzles to scientific problem solving, Polanyi suggests that:

> Each worker could take some of the pieces from the pile and try to fit them together. That would be an efficient method if assembling a puzzle was like shelling peas. But it wasn't. The pieces weren't isolated. They fit together into a whole. And the chance of any one worker's collection of pieces fitting together was small. (Rhodes1986:34)

The same logic can, and should, be applied to problems extending beyond the purely scientific realm. Collaboration between various fields is a necessary component to effective

problem solving. No problem can be solved without addressing a variety of factors, all of which interact in complex ways.

One of the primary aspects of this project that appealed to me was the chance to look at a case in which science has significant real-world implications for a large number of people. One of the most frustrating aspects of laboratory classes for me is the feeling of futility. While they teach valuable techniques, it has always been difficult for me to become engaged by a test that will only lead to the confirmation of something already known. The greatest value of science is in its ability to inform, educate, and effect positive change in our world. Tests and surveys are a crucial component to constructing appropriate and effective policy, whether it is for public health or resource protection. Without independent, un-biased scientific analysis, there is no guarantee that public policy will sufficiently address the needs of a community. In fact, there should be little surprise when it does not.

Much of the scholarly literature regarding the nuclear testing program of the U.S. in the Marshall Islands, for example, focuses on the inadequacies of public policymakers, which are great, indeed. Particularly upsetting in the case of the Marshall Islands is how national defense policies were able to pervert both science, which should be an empirical evaluation of facts, and scientists. The extent to which "scientific" data were altered, bent, hidden and obscured in every possible manner to fit the political agenda of the day is astounding. Frankly, as a scientist, I am offended. While scientists like Robert J. Oppenheimer, the director of the Manhattan Project, charged with the construction of the first atomic bomb, had doubts, they ultimately decided to push forward with the project, literally setting off a chain reaction of worldwide devastation.

While I believe this is generally an accurate assessment, I don't believe the story is quite this simple. It is not as easy as saying that the political atmosphere stifled science, for this

ignores the free agency of scientists. It neglects the fact that many scientists *were* enthusiastic about their projects in pursuit of the unknown and instead reduces them to puppets of the political machine. Because of this, I submit that the finger of blame has not been properly pointed. In fact, a single finger of blame is not appropriate for this situation; the story is not that simple. From the discovery of radioactivity's potential use in weapons of mass destruction, to the medical tests performed on human radiation exposure victims, to the inadequate soil testing that led to the premature return of Marshallese citizens to a dangerously contaminated island, scientists have been accomplices in the destruction from the start. Without their compliance, the Marshallese would not be exiled, contaminated and justifiably upset about the devastation of lives and communities since 1946.

This thesis is framed around the question of what happens when politics and science collide. At each important step of the way, science failed to stand on its strong, empirical legs, instead choosing -or being forced, a fine distinction which is debatable and will be addressed in the following chapters- to submit to the will of the government in the name of national security. Who is to blame is dependent on who had access to what information, when they acquired it, and what they chose to do with it. The answers are not always clear, especially when it comes to documents classified for "national security" purposes. In some cases a best guess must be put forth based on the availability of data. I am not absolving policy makers of any wrongdoing, nor am I placing all of the blame solely on the shoulders of inquisitive scientists. Like most cases, the murky truth likely lies somewhere in the middle.

Instead, what I am endeavoring to understand is how the U.S. was able to devastate a landscape and a people and also fail so miserably in dealing with the fallout, both chemical and social. By understanding how this happened, I hope that we can prevent similar events from

occurring in the future. The thesis is an argument not only for well-informed and responsible public policy, but for well-informed and responsible science as well. What happened in the Marshall Islands is a cautionary tale about what can occur when scientific inquiry loses its moral compass, especially during wartime, where the stakes are high. This problem is not one unique to the Marshall Islands in the mid-20th century. Alfred Nobel faced a similar dilemma with the invention of dynamite, the commercially useful, explosive form of nitroglycerine, in the 1860s. Similar to many atomic scientists on the eve of the Hiroshima bombing, Nobel lauded his invention as a peacemaking tool, one that would end wars more quickly and with fewer casualties (Preston 6). The question of what to do with scientific knowledge will always be pertinent, and as a scientist, and a citizen, I see a great need to address this issue. I can only hope that others do the same not only for our sakes, but for the future of humanity and our planet.

-J.D.S.

I. The Anatomy of the Atom

The Discovery of Radioactivity

"Men love to wonder, and that is the seed of science." *–Ralph Waldo Emerson*

For hundreds of years miners in the Erz Mountains in Czechoslovakia had been digging up an unusual dark-grey mineral, dubbed pitchblende. It was not until the final decade of the 19th century that Henri Becquerel, a French scientist, discovered a unique property of this substance: it emitted invisible rays that could turn a photographic plate black without exposure to light. Even when trapped in a pitch black box, these rays were still emitted, leading Becquerel to conclude that the energy source was contained within the mineral (Miller 13). Despite this deduction, no one knew what caused this mysterious phenomenon.

Intrigued, French scientists Pierre and Marie Curie investigated further. In 1898, the Curies succeeded in isolating two previously undiscovered substances, both of which were dark, heavy and metallic, which they named radium and polonium. They also discovered that radium gave off a radioactive gas, meaning that the atomic structures of these chemicals were changing as these rays were emitted, in a process we now know as radioactive decay (Rhodes 42). German physicist Max Planck also theorized in 1900 that this energy given off is contained always in discrete packets, known as quanta. When electrons "jump" from one energy level to a lower one, energy is released in the form of light. This discovery heralded the beginning of quantum theory and an understanding of radiation (Miller 14).

Meanwhile, a New Zealand scientist named Ernest Rutherford, had been studying the structure of the atom. In 1906, he found evidence for the presence of a positively charged nucleus in his most famous experiment by shooting positively charged alpha particles at a sheet of gold foil. Although most of the alpha particles passed directly through the atom, much to Rutherford's surprise some were scattered, bouncing off in different directions. This result was

as surprising "as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you" (Rhodes 49). From this, he concluded that an atom's mass is concentrated in the nucleus, rather than distributed throughout the atom like the previous "plum pudding model" had suggested. This groundbreaking discovery, that the majority of an atom's mass is concentrated in the nucleus, provided the basis for much further scientific inquiry of the time.

Building on Rutherford's work, Niels Bohr theorized by 1912 that electrons, negatively charged particles, surrounded the positively charged nucleus and, furthermore, were arranged in distinct energy levels. This "Rutherford-Bohr" model of the atom is still accepted today.

In 1932, James Chadwick made an important breakthrough in atomic science. He discovered that positively charged particles, or protons, were not alone in the nucleus; neutral particles, or neutrons, are also present. So momentous was this event that it led physicist Hans Bethe to remark that before 1932 was the "prehistory of nuclear physics and from 1932 on the history of nuclear physics" (qtd. in Rhodes 165). Before the discovery of neutrons, scientists were baffled as to how the increase in atomic weight was not linear, but yet the charge remained neutral. For the atom to remain electrically neutral, electrons must be added at the same rate as protons. Chadwick ultimately discovered that neutrons account for the difference in atomic mass and atomic number, or the number of protons in the nucleus. The greatest implication of this discovery was the possibility of using the neutron, or a beam of neutrons, to probe the atomic nucleus, a feat previously impossible. The atom's secrets were no longer hidden.

Weapons of Destruction

"There are those about us who say that such research should be stopped by law, alleging that man's destructive powers are already large enough. [..] Personally I think there is no doubt that sub-atomic energy is available all around us, and that one day man will release and control its almost infinite power. We cannot prevent him from doing so and can only hope that he will not use it exclusively in blowing up his next door neighbor." *–Francis Aston, 1936*

Prophetically, H.G. Wells' 1913 book, *The World Set Free*, described a source of energy known as "atomic disintegration." In it, he hypothesized about the use of this atomic energy source for constructing "weapons of destruction" (Miller 15). Dismissed as pure fiction at the time, most scientists believed an atom's energy was trapped, that atoms were indivisible (Ungar 25). Only twenty years needed to pass before Wells' vision became all too true.

Rutherford, for one, thought the idea of tapping into energy within the atom was simply absurd. But Einstein was not so quick to dismiss Wells' notion of atomic energy, having already theorized in 1905 that energy was in fact trapped inside the atom. It was just a question of whether or not it could be liberated as Wells envisioned. Leo Szilard, a Hungarian student of Einstein's, also saw some merit in the idea. He believed that a measurable amount of energy could be released from the atom if he could find a fissionable element that, when split, would release energy along with neutrons that would continue to split other atoms, propagating a chain reaction. The release of neutrons was essential for sustaining the reaction. He just needed the right element.

In 1938, a German scientist, Otto Hahn, was studying the effects of bombardment on heavy elements by shooting neutrons at a sample of uranium. The product of this experiment contained traces of barium, a result that perplexed Hahn. Physicists Lise Mietner and Otto Frisch theorized that the barium was a result of the splitting of uranium atoms by nuclear fission. When Bohr heard this idea, he was immediately convinced that they were correct and that this was indeed proof of how one could successfully split an atom. Here was the fissionable element that Szilard had sought (Miller 17).

With this discovery, many began to worry that Wells' theorized "weapons of destruction" could in fact become reality. Questions about the implications of this scientific knowledge

immediately arose. Despite these hesitations, research continued. It was still unknown whether this fission would be sufficient for the development of nuclear weapons: if neutrons were not released when uranium decayed, there would be no fuel to drive a chain reaction. To answer this question, Szilard duplicated Hahn's test, this time with equipment capable of detecting if neutrons were emitted. The results were conclusive: neutrons were in fact released in this reaction, and in 1939, more than 20 years after Wells' literary prediction, Szilard had proved that the concept of a nuclear bomb was in fact feasible.

As with any great scientific discovery, this knowledge came with great pressure. Scientists are charged with using such information in a responsible manner. Some believed that the pursuit of atom splitting was too much like playing God and feared the potentially disastrous consequences:

> Right from the start of this enterprise most scientists realized that they were not simply creating a much bigger bang. They were toying with one of the ultimate forces of nature. Yet in the end, these scientists were as much the victims as the initiators of the drama. (…) The uranium pile was the philosophers' stone. They were caught up in the drama of the Manhattan Project and (…) in the testing and display of their omnipotence. (Ungar 1992: 32)

Now that the development of an atomic bomb was a potential reality, this created an intense dilemma for the scientists involved: how should they proceed? Szilard advocated for the creation of the Association for Scientific Collaboration, a civilian organization essentially designed to keep watch over the development of atomic energy. Eugene Wigner, another prominent physicist of the time, argued that the information was too great to keep hidden and suggested that scientists inform the U.S. government of their latest discovery. Others argued that

the information should be kept secret, unpublished, for fear that Nazi scientists would take advantage of the discovery and beat the U.S. to the bomb. (Rhodes 292). This concern was particularly salient since many of the scientists involved were Jewish refugees who were extremely worried about the threat of a German bomb (Ungar 33). Despite the evidence, Bohr was of the opinion that nuclear energy would never come to fruition due to the difficulty of isolating enough uranium. In addition, he argued that "openness was its [physics'] fragile, essential charter, an operational necessity, as freedom of speech is an operational necessity to a democracy" (Rhodes 294). He warned against secrecy, which is not in the nature of true scientific inquiry. After much debate, the physicists agreed to share their thoughts on the feasibility of atomic fission as a possible energy source with the U.S. Navy as well as publish a very hesitant article speculating about its use in explosive technology. At first, government officials were wary about the idea of the atomic bomb. Echoing the skepticism of the physicists themselves, many believed that finding, isolating, and compiling enough pure uranium would prohibit the development of the process and thus gave the matter little further thought.

Meanwhile, scientists continued searching for answers to the problems posed by the present limitations physical knowledge. The first challenge was finding an efficient method of separating the two main isotopes of uranium U^{235} and U^{238}. The difference in the atomic number, which is equal to the number of protons plus neutrons, is due to the difference in number of neutrons in the nucleus of these two isotopes. U^{235} contains three fewer neutrons than U^{238}, making it lighter, more unstable and consequently more easily fissioned, an ideal weapons material. The challenge for scientists was how to isolate U^{235}, which comprises less than 1% of naturally occurring uranium (Rhodes 298). When this was mastered by scientists at the

University of Minnesota in February of 1940, scientists were one step closer to making the atomic bomb a reality.

A Dangerous Chain Reaction

"Technological progress is like an axe in the hands of a pathological criminal." –*Albert Einstein*

Other concerns arose. Large quantities of uranium existed in Czechoslovakia, at the time mined by Belgium. Szilard and others began to worry about the consequences of Nazi Germany getting hold of this stock (Rhodes 303). Sufficiently nervous, Szilard approached Albert Einstein in hopes of using his contact with the Queen of Belgium to dissuade Belgium from selling this uranium to the Germans. Hesitant to approach the queen directly, Szilard and Einstein instead drafted a letter to a member of the Belgian cabinet. Along with Wigner, Einstein and Szilard agreed that it was prudent to alert domestic leaders, especially President Franklin D. Roosevelt, before contacted Belgian officials. Einstein drafted a letter which was letter presented directly to President Roosevelt by Alexander Sachs, a biologist, economist and familiar face in the White House. This letter suggested that a liaison between the government and physicists working on development of nuclear chain reactions be appointed. They were careful in how they presented the potential uses of atomic energy; "bombs of hitherto unenvisaged potency and scope" was listed third only after energy production and medical uses. Still, the message was clear to Roosevelt, who correctly concluded "what you are after is to see that the Nazis don't blow us up" (Rhodes 314).

Following Sachs' presentation, President Roosevelt convened an Advisory Committee on Uranium. At the first meeting of the committee, Szilard along with Wigner, Teller and Sachs argued for the development of a nuclear energy research program. Army representatives were less enthused, bashing the idea of a new powerful weapon that would change the course of the

war. Only reluctantly did the committee eventually agree to fund Szilard's project, an attempt to generate a sustained nuclear chain reaction (Miller 19). The committee's 1940 report stated that the research was to explore nuclear chain reactions as a potential power source in submarines, again with only a minor note towards weapons uses.

Repeatedly masking the true purpose of this research, first in Einstein's letter and again in the report, likely made it easier for physicists to justify these experiments. This is not to say that there was not legitimate interest in peaceful uses of atomic energy, like power generation, but most scientists saw the writing on the wall: they knew war was coming and in 1939 it began. Enrico Fermi, an Italian physicist, just barely escaped fascist Italy in 1939, fleeing to the U.S. where he began conducting fission experiments at Columbia University. Atomic scientists, including Fermi, faced a dilemma that stemmed from the incompatibility of the free exchange of ideas and the global political situation. From the start, they argued the necessity of developing nuclear technologies lay in deterring the Nazis. By 1940, with Hitler's power spreading across Europe, the threat of war and the potential consequences of German nuclear capabilities made the situation more precarious. By assuming a defensive standpoint against a deserving enemy, scientists never thought of themselves as destroyers, but rather protectors. This preoccupation allowed them to believe that "they were preparing a new force that would ultimately bring peace to the world" (Rhodes 312). At this point, they may have very well honestly believed that building weapons of mass destruction would assure world peace. And the alternative, risking Germany possessing unmatched nuclear technology, was simply not an option.

The Manhattan Project

"Almost everyone knew that if it were completed successfully and rapidly enough, it might determine the outcome of the war. Almost everyone knew that this job, if it were achieved, would be a part of history."
–Robert J. Oppenheimer, 1942

With Great Britain preoccupied with fighting the Germans, much of the onus of building an atomic bomb for the Allies fell on the U.S. Led by Robert J. Oppenheimer, a professor of physics at UC Berkeley, scientists of the Manhattan Project worked at Los Alamos Laboratory in New Mexico to develop an atomic bomb. Beginning in 1942, the Manhattan Project was the intentionally deceptive name given to the research project tasked with the goal of creating an atomic weapon. The formation of this team also signaled a fundamental shift in the way scientists and governmental organizations were willing to view nuclear technology as a project explicitly focused on weapons development, not generic atomic science.

One of the biggest technical challenges scientists of the Manhattan Project faced was the problem of "going critical." When too much plutonium or uranium is stored together in a small space, spontaneous fission occurs. Neutrons radiating naturally begin striking other nuclei, releasing doses of harmful radiation to bystanders, at best, and, at worst, prematurely setting off an explosive reaction. Finding this "critical" amount was essential to developing the bomb. Scientists tested this via a dangerous game of trial and error, adding more uranium to a sphere until the material went supercritical, as measured by a Geiger counter in the room, and then removing the uranium to return to sub-critical levels. To complicate matters further, scientists discovered that when working with near-critical masses of U^{235}, their own bodies could reflect neutrons, tipping the load past critical. No doubt early nuclear weapons scientists were working in extremely precarious positions, for which they suffered the health consequences (Miller 23).

There was also the problem of assembly. If the critical mass was assembled too slowly, the material would release radiation into the room but lack the explosive quality necessary for a bomb detonation. One early solution to this problem was to shoot a bullet at a sub-critical mass of uranium, but this was inefficient. If the bomb disintegrated before reaching critical assembly,

it would not detonate. It would become a dud, landing on enemy soil with an already distilled packet of weapons-grade U^{235}. A better solution, the one ultimately utilized, was implosion. This would ensure that the material was held in place while the neutrons began the reaction. For this technique to work, exacting precision was needed to ensure that the shock waves generated by the explosive shell reached the core at the same moment. There was no room for error in calculations or construction. In 1945, theory was ready to be put into practice when the scientists of the Manhattan Project assembled their first test bomb.

Fingers Crossed

"I am sure that at the end of the world, in the last millisecond of earth's existence, Man will see what we have just seen." -*George Kistiakowsky, present at Trinity detonation*

In July 1945, the U.S. was ready to test its first atomic weapon at the White Sands Missile Range, 35 miles outside of San Antonio, New Mexico. Calculations were checked and rechecked in the final days leading up to the first test. Despite the best predictions, it is a simple fact that nobody could be entirely sure what would happen when the bomb was detonated. Questions were raised as to the possibility of igniting the atmosphere. According to Manhattan Project scientists, the chances of this outcome were three in one million, which, although small, is not zero. Just days before the first bomb was to be tested the manager of the Manhattan Project, General Leslie Groves, prepared press releases for all possible outcomes. Demonstrating how little scientists knew about what to expect, one read: "A mammoth explosion today resulted in widespread destruction of property and great loss of life" (qtd. in Miller 34). With fingers crossed, the first detonation, code named Trinity, was scheduled for July 16, 1945.

Early on July 16th, scientists were worried. A violent thunderstorm lit up the skies of New Mexico. Luckily, as the detonation hour approached, the skies cleared and the test

proceeded on schedule. At 5:29:45 a.m., the world's first nuclear bomb was detonated. An electrical charge from the capacitor was released to the detonator, which fired the explosive shell, sending blast waves directed to the core. These waves crushed the uranium "hammer", which forced the sphere into a super dense ball, sending the device into a super-critical state. At the center of the bomb, polonium and beryllium were mixed, sending neutrons scattering into the surrounding plutonium to begin the fission process. When these neutrons reached the surface of the sphere, billions of plutonium atoms were fissioned within a few hundred millionths of a second. When the plutonium disintegrated, massive quantities of energy were released and the bomb exploded. This explosion generated a fireball as tall as the Empire State Building and half a mile wide, vaporizing soil around ground zero (Figure 3).

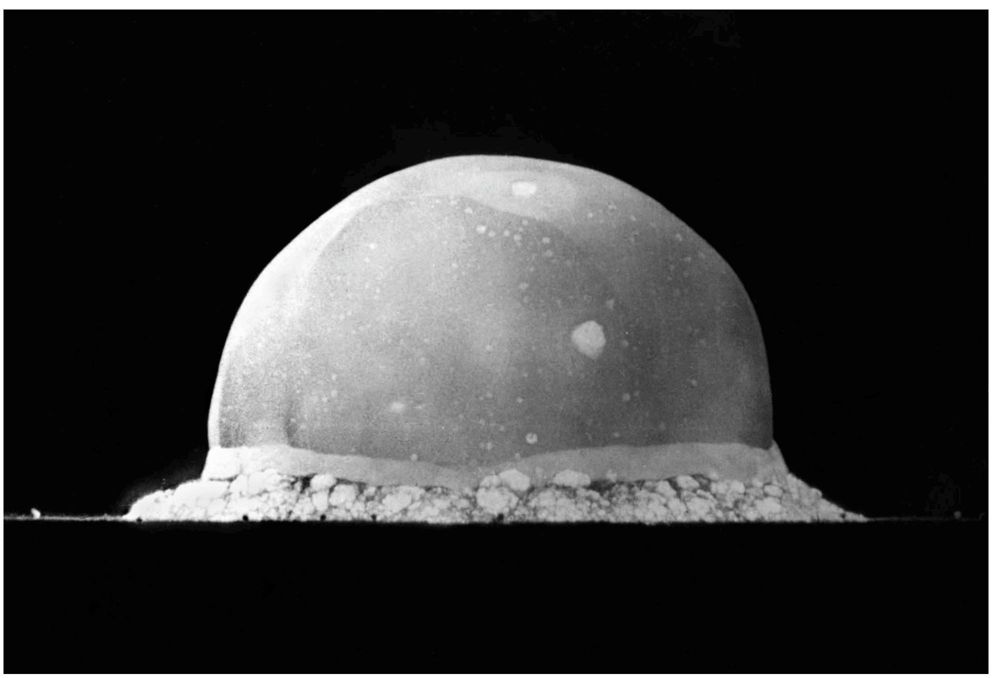

Figure 3. Trinity test explosion. (rhapsodyinbooks.wordpress.com)

Watching this explosion from a distance, Oppenheimer reflected on a line from the Bhagavad-Gita, his now famous quote: "'I am become Death, shatterer of worlds'". The Nuclear Age had erupted.

II. The Perfect Proving Grounds

Between a Rock and a Hard Place

"The universal reaction of Los Alamos scientists has been amazement that they thought and said so little. So great was the absorption in the immediate task, they point out, that people of more than normal sensitivity to moral issues, who later became very active in the fight to control the bomb, accepted assignment in the Pacific without question." *–Alice Smith, 1965*

After all of the time and money poured into the Manhattan Project, there was a great need to justify this effort. The German defeat in 1945 removed Hitler's Nazi Germany as a potential target. Instead, focus shifted towards the potential use of nuclear weapons against Japan. Following Roosevelt's death in April, President Truman faced the difficult decision of whether to use the bomb, and if so, whether to detonate a demonstration bomb first. The unwillingness of the Japanese to agree to unconditional surrender led the U.S. government to increasingly believe that dropping an atomic bomb on Japan would hasten the end of WWII and drastically reduce the number of allied troop casualties. Truman also worried that if the war continued, a Russian invasion of Japan was extremely likely. James Byrnes, Truman's secretary of state said of Truman that "his views were the same as mine—we wanted to get through with the Japanese phase of the war before the Russians came in" (qtd. in Preston 332). The question of whether or not the bombs dropped on Hiroshima and Nagasaki were truly necessary to end the war is still debated and beyond the scope of this thesis. Suffice it to say that the U.S. decided to proceed, without a demonstration detonation, to detonate two atomic bombs on Japanese cities, resulting in their complete destruction. This was the first and, to-date, only time that nuclear weapons have been used in active war. This was also the first time that a population had been exposed to radioactive material, the effects of which were still poorly understood. Beyond individuals, often researchers working in close contact with radioactive substances, little information was available about the health impacts of radiation exposure.

After the detonations of the atomic bomb at Hiroshima and Nagasaki, researchers were sent to Japan to evaluate the impact, including Earle Reynolds, an anthropologist working with radiation victims as a biostatistician at a Hiroshima hospital (Price 56). His first-hand experience with bomb victims led him to adopt a strong anti-nuclear stance after witnessing the physical and psychological suffering of the affected individuals. Angered by the "antiseptic tone" of many other scientists, Reynolds identified with his research subjects as people, not just numbers. The practice of distancing oneself from the issue at hand with clinical language is sometimes necessary component of science, but it is also a dangerous practice. On one hand, it allowed researchers to work in emotionally trying settings without becoming immobilized by emotion. On the other hand, it is also what allowed many Cold War scientists to continue with nuclear research at the cost of human life and well-being. Researchers, especially those working with human subjects, have the difficult challenge of finding a way to conduct their research with the right balance of empathy.

Some scientists were more successful at this than others. By dehumanizing those affected by nuclear bombs, in this case the Japanese at Nagasaki and Hiroshima, as simply data points, *enemy* data points, some researchers were able to justify future testing as necessary science. Any data that did not fit neatly into this picture was dismissed, like Reynolds' 1954 "Report on a Three-Year Study (1951-1953), of the Growth and Development of Hiroshima Children Exposed to the Atomic Bomb," which remained unpublished due to fabricated accusations of faulty statistical analysis (Price 62-3). In actuality, the report was suppressed due to the unfavorable image it presented of the atomic bomb's human impact. Unable to go public with his data independently due to national security limitations, Reynolds' was immobilized by "political forces [that] created a gravitational pull that narrowed the range of acceptable

interpretations of data," limits which "had serious consequences for those exposed to radioactive fallout" (Price 63). In other words, because Reynolds' conclusions were not in line with the political agenda of the day, they were suppressed. This left little data available for protesters of nuclear weapons development to cite.

Following WW II, the perceived threat of communism in the U.S. was rapidly growing, leading to the rise of the Cold War era. As the relationship between the U.S. and the USSR deteriorated, the two countries became embroiled in a steadily increasing nuclear arms race. Former Manhattan Project scientists, now somewhat more concerned about the fruits of their labor, had difficultly stepping down from their posts without their loyalty being questioned, making "scientists among the first victims of the post-World War II red scare" (Wang 49). Scientists who advocated for international exchange of information were accused of being communist-sympathizers, at best, or outright Soviet spies, at worst. Not only did this make it particularly difficult for individual scientists to work, but it also "silenced alternative political discourse, thus undermining the foundations of American democracy" (Schweber 116). Although sometimes carried to an extreme, particularly during McCarthy era of the 1950s, what complicated matters further was the real presence of Soviet spies within the U.S. scientific community. During the final years of WW II, several scientists were caught passing along atomic secrets to the USSR. Considering the sensitive nature of much of the atomic research being conducted, the U.S. government had a legitimate reason to be concerned about the fate of those data. Unfortunately that concern escalated to downright paranoia at times, leaving very little room for any dissenting scientist to make their views heard. Essentially it became an issue of either supporting the government's research efforts, and accompanying nuclear proliferation, or risking one's career and reputation.

The American ambition to expand its nuclear test program resulted from the "need" to further refine and stay ahead of Soviet nuclear technology. Between 1950 and 1962, the most active testing was conducted by the former USSR (219 tests), the U.S. (217) and the U.K. (33) (Kirchmann and Warner 13). It is through this testing that nuclear states were able to advance technologies from simple fission devices, based on implosion of a bulky plutonium center, to more advanced thermonuclear bombs. More complex, these weapons required multiple test runs to perfect. Following the initial test at Trinity, from 1951 until 1962 the U.S. government used the Nevada Test Site to detonate and evaluate "lower yield" atmospheric tests and underground tests. For "high yield" atmospheric tests, those that released a significantly larger amount of radiation into the environment, the government looked for an isolated, relatively uninhabited location. Consistent weather patterns, relatively small number of inhabitants, and isolation in the middle of the Pacific Ocean all made the Marshall Islands seem an ideal test location. The Marshall Islands, especially Bikini and Enewetak atolls, would prove a useful alternative to nuclear weapons testing in Nevada, which, by 1953, was a growing concern at home. Although, and to some extent because, precise data on the Nevada testing were unavailable to the public, people became worried about the mysterious, potential health effects of the locally detonated bombs. In particular, the relatively large amount of fallout from the 1953 Upshot-Knothole test series brought the issue to light in many local communities. Public concern continued to grow through the 1950s and early 1960s, increasing the need to find an alternative test site.

The Marshall Islands: A Convenient Acquisition

Located in the midst of Pacific Ocean just north of the equator and west of the international dateline, what today is known as the Republic of the Marshall Islands (RMI)

consists of twenty-nine atolls and five islands. Together, the islands comprise an area of 70 square miles, roughly the size of Washington D.C., a diminutive size that is difficult to imagine considering the islands are spread across a patch of ocean approximately the size of Mexico. With an average elevation of only six or seven feet above sea level, the Marshall Islands contain no mountains or rivers. *Ratak*, or sunrise, and *Ralik*, sunset, are the names given to the two island chains of Marshall Islands in the east and west, respectively (Barker 4-7).

Settled thousands of years ago by migrants from Melanesia, it was not until the 1500s that European explorers reached the Marshall Islands (Barker 16). Desired for their location as an ideal rest stop for trans-Pacific ships, as well its thriving copra (dried coconut meat) production, the Marshall Islands passed from Spanish possession to German rule in the late 19th century. Japan captured the islands from Germany during World War I and retained authority until 1944 when U.S. forces defeated the Japanese and following WW II were given authority over the islands by the UN (Barker 17). Today, the RMI is an independently governed nation in free association with the United States.

Life on the Marshall Islands can be difficult due to the dry conditions along with limited resources, including food, water and land (Barker 8). Many of the atolls contain little to no soil, making conditions less than ideal for crop cultivation. Early anthropologists characterized the area as one that was unfit to sustain a human population. This assessment does not take into account the ingenuity of the Marshallese and their practice of cultivating resources from not only their individual islands but the ocean and other nearby islands as well. In their eyes, their home islands were anything but "barren sandbars." This characterization also neglects to take into account the ancestral connection the Marshallese people have with their land. Unlike in western society, the Marshallese do not believe that land could be owned or sold; it was passed from

generation to generation through the matriarch of the family (Barker 9). The family that resides on a particular parcel of land has rights to use it, but the notion of individual property ownership does not exist. Emphasis is placed on sustainable land use, as it will remain in the family and provide the livelihood for future generations. As Wilfred Kendall, a Marshallese elder, explained:

> "The resource people treasure most is land. Land speaks of your essence, reason for living. You relate to the world in terms of land [that] provides for your present, future and future needs. […] How do you put a value on something that people consider as a living thing that is part of your soul?" (qtd. in Barker, 2008: 63)

This connection to the land is also highlighted by the Marshallese language. Names are assigned based on the historical, physical and social significance of individual places. For example, Rongelap, one of the northern Marshall Islands, literally translates to "atoll with large lagoon" (Barker 13). Reefs and seamounts are also given names, indicating that these areas are equally important to the Marshallese cultural landscapes. Notably, the Marshallese concept of productive area is not limited to land, but also includes the sub-aquatic world. Not only are these areas economically important, providing a large source of fish, a staple of the Marshallese diet, but they are spiritually significant as well, relationships that often were disregarded by American officials.

Considering the limited land area with which they work, the Marshallese have a very good idea of what it means to be environmentally responsible. Instead of exploiting one's own island, the Marshallese travel to nearby islands and atolls to disperse their impact, insuring the resources will not become depleted. For example, residents of Rongelap frequently traveled to nearby Rongerik atoll, known as "the atoll of birds and turtles," to obtain food (Nerja Joseph,

interviewed by Barker, 2008, 77). With responsible management, the Marshallese were never at risk of starvation and resources were generously shared throughout the community. The arrival of U.S. military and nuclear testing disrupted the Marshallese way of life, even in places that were not heavily contaminated. Radiation made travel between islands and the sharing of resources, a central component of Marshallese society, all the more dangerous.

Testing Begins

In 1946, while the Marshall Islands were still under the control of the U.S. Navy, U.S. Naval Commodore Ben Wyatt first approached the Bikinians about temporarily vacating their island so that the U.S. could "learn how to use it [the atomic bomb] for the good of mankind" (Weisgall 107). Couching the request in biblical terms, Wyatt convinced the leaders and people of Bikini to make this sacrifice for the U.S., the benevolent nation that had liberated them from the Japanese military rule. The 167 residents of Bikini Atoll were then relocated to Rongerik Atoll in preparation for Operation Crossroads, the first series of nuclear weapons tests conducted in the Marshall Islands (Barker 219). The U.S. also evacuated the islanders residing on Rongelap in the summer of 1946 due to their proximity to Bikini Atoll (Johnston and Barker 89). In both of these cases, the resources present on these new islands were insufficient to sustain the displaced islanders. The Rongalapese were returned to their home shortly after the completion of Operation Crossroads, however the contamination of Bikini Atoll prevented the reestablishment of the community who remained exiled on Rongerik.

Reports of these first Bikini tests were heavily censored before information was released to the U.S. public. Careful not to cause panic, nor compromise national security, these initial reports downplayed the strength and damages of the Able blast. There was little reference to

widespread radiation contamination and CBS reporter George Moorad worried that the story presented to the public "would doubtless foster the impression that atomic power was nothing more radical than the refinement of TNT over Chinese gunpowder" (qtd. in Smith 478). International reports were quick to chastise the U.S. for using such a weapon, suggesting that the U.S. was more concerned with perfecting nuclear weapons technology than establishing safety restrictions on its usage. In the coming months, more data came to light and reports contained more accurate information about the damages to the naval ships. Another reporter, William Laurence, worried that the actual data obtained from the tests was secondary to the impact that data had on public opinion of the atomic bomb.

> "Before Bikini the world stood in awe of this new cosmic force… . Since Bikini, this feeling of awe has largely evaporated… . [The average citizen] had expected one bomb to sink the entire Bikini fleet, kill all the animals aboard, make a hole in the bottom of the ocean and create tidal waves that would be felt for thousands of miles. Since none of these happened, he is only too eager to conclude that the atomic bomb is, after all, just another weapon. As such it is a problem concerning only the military and nothing for the average citizen to be worried about." (qtd. in Smith, 1965: 480)

Essentially, the "failure" of the bomb to cause massive, tangible destruction led many to false underestimations of its capabilities. The fact that the contamination caused by radioactive fallout is largely an invisible threat, and one that the U.S. public was unfamiliar with in 1946, made it easier to dismiss the damages caused by nuclear testing in the Pacific.

In 1947, one year after Operation Crossroads, the UN transferred control of the Marshall Islands from the U.S. Navy to the U.S. government. In exchange for the use of this strategic

territory, the U.S. was charged with the task of "protect(ing) the inhabitants against the loss of their lands and resources" (UN Trusteeship Council 1958). The U.S. had a clear responsibility to promote the welfare of the people of the Marshall Islands. This charge was entirely disregarded: the subsequent nuclear testing was conducted at the expense of all aspects of Marshallese society, including their land, lagoons, economy, health, political life and social structure. Following Operation Crossroads, the Joint Chiefs of Staff concluded that large-scale research and development was necessary for national security. Between 1946 and 1958, the United States performed sixty-seven atmospheric, land, and underwater nuclear tests in the Marshall Islands, exposing the islands to the equivalent of 1.6 Hiroshima sized bombs every day for those twelve years (Johnston and Barker 214). Many of the highest yield U.S. tests were performed on Eniwetok and Bikini Atolls (Kirchmann and Warner 18). Nearly 80 percent of all U.S. nuclear tests ever conducted took place in the Marshall Islands and almost half of these tests had higher yields than any of the bombs tested at the Nevada test site (deBrum). Six coral islands were completely vaporized by testing, leaving only ocean in their wake. Other islands, like Bikini atoll, have a large crater visible to the eye (Figure 4).

Figure 4. ***Bikini atoll.*** Here the crater created by a nuclear test bomb is clearly visible. (Google Maps)

Bravo?

"How do we think that the world is going to look at us if we continually use places and then abandon them? That is why people are starting to look at us as the evil empire, if anything else. Because we go someplace, they open their arms to us and then when we are done with whatever we need for our benefits we just walk away like there is no return. There is something wrong with that. (…) I mean these are human beings that live on these islands." *–Gregory Meeks, 2007 Congressional Hearing*

Not only were islands vaporized, but hundreds of Marshallese were exposed to lethal amounts of radiation as a result of the largest nuclear test ever conducted by the U.S. in 1954, code named Castle-Bravo. At fifteen megatons, one thousand times the size of the bomb dropped on Hiroshima, this bomb was intentionally designed to cause as much local fallout as possible so that scientists could study the environmental effects of radiation (Barker 23). The site was originally chosen in part due to the south-easterly winds that would typically direct any fallout towards open ocean, away from populated islands. A wind shift before the detonation combined with an unexpectedly high yield lead to the radioactive contamination of Bikini atoll and nearby Rongelap and Utirik atolls. There is evidence that military commanders in charge of the detonation had ample warning from meteorologists about the weather change before the test, with reports indicating winds were headed straight for Rongelap. These reports were met with remarkable arrogance and disregard for public health, exemplified by the D.W. Clarkson, the Commander of the task force charged with running the test program who "proposed to 'treat the report the same as I would a report from any other member of my staff when I do not agree with him. In short, we will kill it and stick it in the file'" (qtd. in Barker 40). In this case, scientific data were present suggesting that human exposure from the Bravo test was likely, but sadly the data were ignored.

In a sharp departure from protocol, the U.S. did not evacuate Marshallese residents living on Rongelap and Rongerik before the Bravo explosion. This has led many critics to assert that the U.S. government intentionally left the residents on the islands to observe the effects of

radiation on people, which, if true, would be a truly disconcerting notion. Maps showing the projected regional fallout were redrawn to exclude inhabited islands without changing any physical parameters of the test (Thomas). These new maps were made essentially to appease the high commissioner of the Trust Territory of the Pacific Islands, Elbert D. Thomas, who requested that the fallout not impact Ailinginae, an "uninhabited" but resource-rich island used by the Rongelapese (Barker 94). Unfortunately, while on paper everything now appeared safe, none of the test conditions had changed. Everything continued as planned and early on March 1st, the U.S. detonated its largest thermonuclear weapon ever, 15 megatons, exposing hundreds of people to lethal amounts of radiation (Barker, "Half-Lives" 220).

Prior to the explosion, U.S. military personnel were given instructions on how to minimize fallout exposure by wearing long-sleeve shirts and pants, as well as avoiding contaminated food and water while remaining in military shelters following the test. The people of Rongelap were not even warned that a test was about to occur. While U.S. personnel were evacuated the following morning, the Marshallese were not taken from their island until removed by boat fifty-six hours later on March 4th. This was not simply a matter of being unable to reach the islanders: military officials returned the day following the test dressed in highly protective suits to take radiation measurements. Locals noted, however, "the speed with which the men surveyed everything in the island and then returned to their plane" and could not help but wonder if that was an indication of how harmed their island was (John Anjain, unpublished manuscript, 1973, in Johnston and Barker 13). Between the time of detonation and evacuation, the Marshallese continued to eat food and drink water that was now laced with radioactivity from the explosion. Children played in the fallout, while others believed that the powder falling on the island "'was something to reduce the poison from the bomb'" (Kajim Abija, interviewed by

Barker, March 18, 1999). The exposed islanders had no information to warn them of the dangers of the radioactive dust and continued to go about their business as usual.

The residents of Rongelap and Rongerik were not the only victims. A group of Japanese fishermen on The Lucky Dragon, a nearby boat, and U.S. servicemen were all exposed to dangerous, in some cases lethal, amounts of radiation. The fishermen as well as the exposed islanders began to show signs of radiation poisoning almost immediately (Figure 5). The fallout clung to the coconut oil that many used in their hair, causing burns to the scalp and causing hair to fall out in clumps. Skin blistered from the fallout, and many people became nauseous, classic symptoms of radiation sickness. When they were finally evacuated on March 4th, the residents of Rongelap and Ailinginae were moved to Kwajalein, south of the heavily exposed area. The migration was made more difficult due to the severity of radiation symptoms afflicting the islanders.

Figure 5. Radiation burns on fallout victims in Rongelap. (US Navy photos)

Once removed from their homeland, the nuclear refugees remained on Kwajalein until 1957 when their islands were declared habitable again. Unfortunately for the Marshallese, this was only the beginning of decades of physical and psychological pain, resulting from the chemical contamination of their home. Evacuation did little to solve their problems. They would soon bear to witness the full extent of its destructive powers, which extend far beyond the initial blast. Although invisible at the time, the damage was done.

III. The Fallout

A Chemical Catastrophe

To predict the impact a particular nuclear detonation will have, several factors must be taken into account. Due to the variety of variables, it is impossible to generalize the effects of one test on a certain population as applicable to all cases. The contents of a radioactive explosion and their distribution by size within the resulting cloud are an important component, but not the only relevant variable (Kirchmann and Warner 33). In addition to particle size, geographical distribution of radioactive debris is also influenced by meteorological conditions (Kirchmann and Warner 52). Once these chemicals are released into the atmosphere, weather conditions have a large influence on where radioactive debris will ultimately land. A change in wind patterns or a particularly stormy day can result in increased contamination in areas that otherwise might have been spared. When designing a transport model, local and global weather conditions at the time of the blast, as well as the hours and days following the detonation, must be taken into account. The importance of this factor is highlighted by the experience of the Rongelapese people after the Castle-Bravo explosion, where a shift in wind patterns had a disastrous effect on the island's population.

When a nuclear bomb is detonated, the explosion creates a radioactive cloud which can rise several kilometers high, depending on the yield of the explosion. The cloud consists of primarily fission products and neutron-activation products, combined with vaporized particulate matter from ground zero, or where the bomb was detonated (Kirchmann and Warner 34). Larger particles tend to fall out of the cloud more rapidly due to their mass, whereas smaller particles can be transported further before eventually settling to the land or ocean. Once these radionuclides touch down, whether on land or water, they are incorporated into the food chain

where consumption patterns of the area's humans, animals and plants will direct the cycling of the contaminants throughout the environment (Kirchmann and Warner 33). In the case of the "unusual radiation accident" that was the 1954 Castle-Bravo test, atmospheric conditions resulted in heavy particulate fallout accumulation, which reached Rongelap and Ailingnae, 160 km from ground zero, 4-6 hours after the explosion. Using a point-source transport model with settling velocity of radioactive particles as the primary variable, fallout patterns can be mapped (see Figure 6 for a map of the fallout distribution).

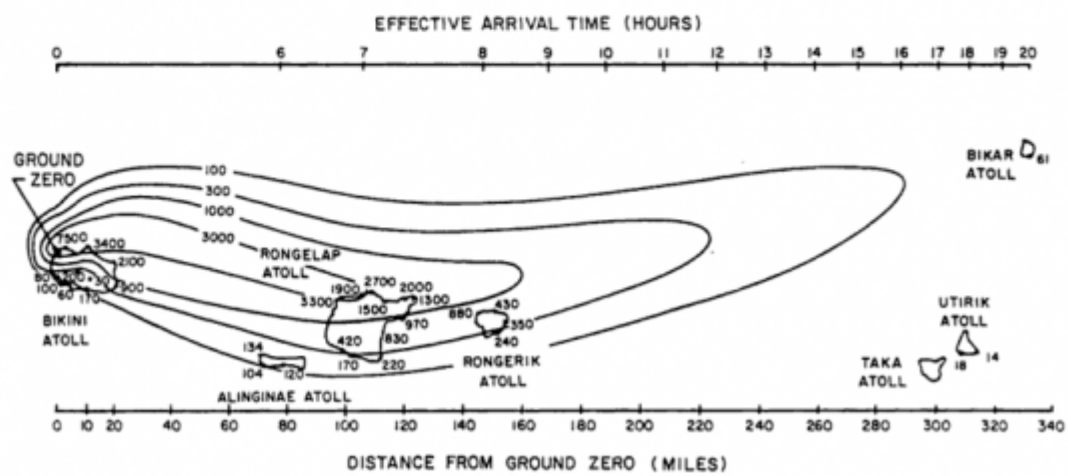

Figure 6. Map of Fallout Distribution from Operation Castle-Bravo, 1954.
(http://nuclearweaponarchive.org/Usa/Tests/Castle.html)

Human Exposure Pathways

Following a nuclear explosion, there are two primary pathways of internal exposure: inhalation and ingestion (Figure 7). Radioactive gasses may be inhaled immediately following the blast as the initial cloud passes, or later as deposited particles are disturbed and consequently re-suspended in the atmosphere (Kirchmann and Warner 99). Models for absorption of radionuclides have been generated by the International Commission on Radiological Protection, ICRP. These models are based on an average "reference man," making predictions for unique

communities living near the largest test explosions more difficult. Important factors in determining inhalation exposure include the time of year of the explosion, location of the person during the passage of the cloud, place of residence and occupation following the cloud's passage (Kirchmann and Warner 100). All of these variables influence the amount of time, and consequently direct exposure, an individual would receive. In the case of the Marshallese, the large amount of time spent outdoors only increased the doses received via inhalation.

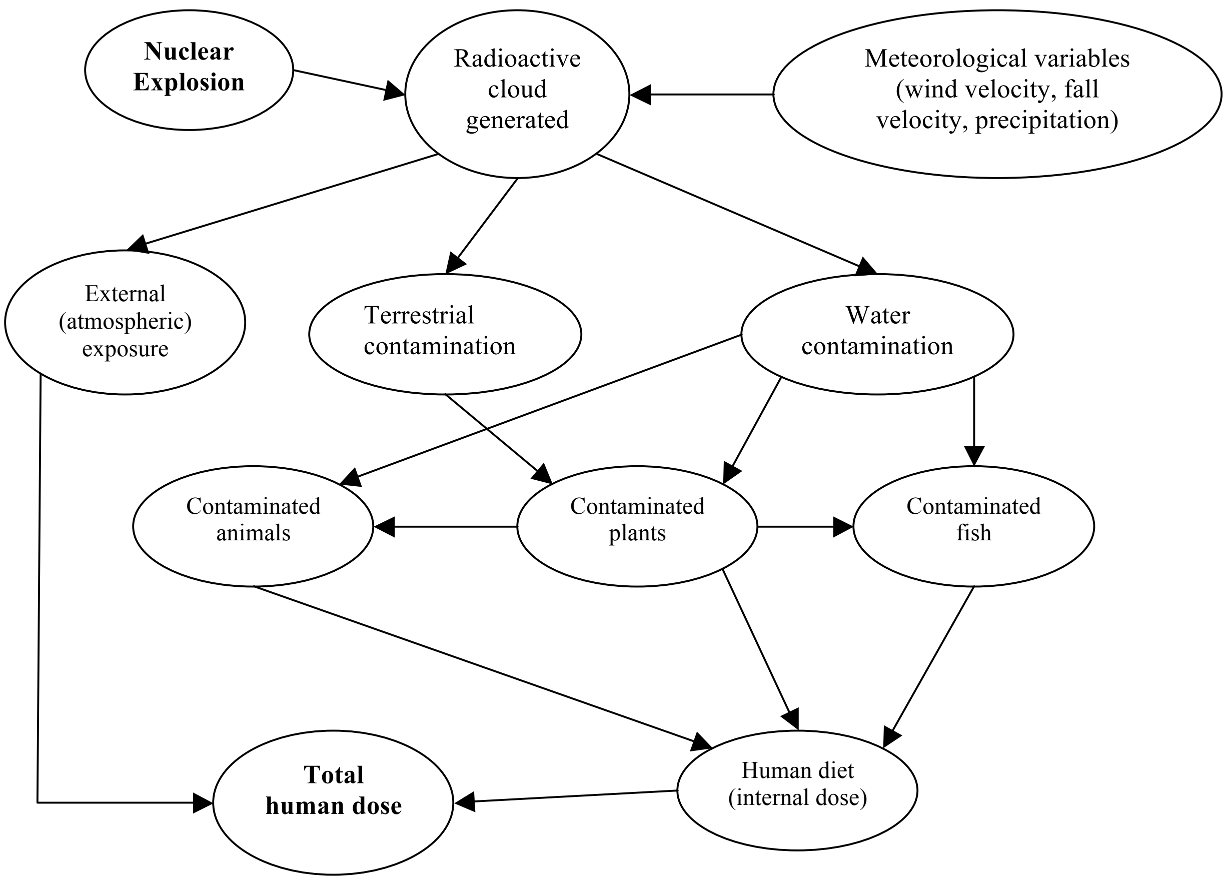

Figure 7. Transport pathways from nuclear explosion to total human dose. (adapted from SCOPE, 2000).

The second primary method of internal exposure is ingestion. The consumption of contaminated plants and animals that have been exposed to radioactive fallout increases the human dose. Plants can be directly contaminated by atmospheric fallout, making them

dangerous for consumption. In these cases, certain methods of food preparation (for example, husking a coconut to get to the inner meat) can significantly reduce the amount of exposure. Deposition from the initial fallout is not the only way in which plants can be affected. The introduction of these radionuclides into the soil can lead to long-term contamination via plant nutrient uptake as plants absorb radionuclides from the soil.

To determine whether immediate, direct contamination or long-term, indirect contamination presents a greater hazard, the specific radionuclide in question must be defined. Not all radionuclides decay, or are naturally removed from the environment, at the same rate. For example, I^{131} is a relatively short-lived radionuclide with a half-life of 8 days, and is therefore less likely to remain in the soil long enough for indirect exposure to occur (Kirchmann and Warner 86). By contrast, long-lived isotopes like Sr^{90} and Cs^{137} can be present in larger quantities for a much longer time, causing significant long-term contamination.

Due its short half-life, I^{131} is more likely to enter the body in significant quantities from consuming milk from contaminated cows and goats than from atmospheric exposure through a process known as bioaccumulation. Approximately 10% of the I^{131} consumed as a result of eating contaminated grass will accumulate in a cow's milk, which can then be passed anyone consuming this milk. Once ingested in the human body, the thyroid gland accounts for 20% of the total I^{131} uptake, which helps explain the high incidence of thyroid cancer seen in radiation exposure victims ("*Impacts of nuclear testing on health and life*"). This is especially dangerous for nursing infants or young children who have much smaller thyroid glands, weighing only 2 grams compared to the 20 g of an adult thyroid, and therefore feel the effects more acutely.

^{137}Cs has a much broader distribution throughout the body. Animals that have consumed plants contaminated with ^{137}Cs will likely store the radionuclide throughout their bodies,

including the parts that are typically prepared for human consumption. Because of this, indirect contamination through this pathway is much more likely for ^{137}Cs than ^{131}I (Kirchmann and Warner 101).

Harrowing Health Effects

When the first atomic bomb was dropped at Hiroshima, no data existed on the biological effects of radiation on humans. This new "dirty" bomb created not only a bigger explosion, but also contained radioactive innards that were strewn across an unsuspecting and unprepared population. While data was collected on the exposed Japanese after the Hiroshima and Nagasaki detonations (see chapter 1), this data was limited. Importantly, no long term data were available due to the bomb's recent debut. The bombs dropped at Hiroshima and Nagasaki were first-edition weapons and as technology improved, further tests were needed not only to assess their explosive capacity but also to determine any "side effects." Here was a new type of bomb where surviving the initial blast did not mean that you had survived the attack unscathed. The physical destruction of a landscape was immediately clear, while the impact on the survivors, short and long term, was still an unknown variable. Luckily for interested researchers, and unfortunately for the unwitting subjects, the nuclear testing in the Marshall Islands provided an ideal population to study the biological effects of the new weapon.

Project 4.1

"We never knew what was going on. There was a time where they took my blood, mixed it with something, and then shot it back into me. They never asked me if they could do this, they just did it. I didn't understand what they were doing and I still don't." *–Chiyoko Tamayose, regarding medical tests performed as a part of Project 4.1., 2001*

As the dust from the Bravo detonation settled, “U.S. researchers were well positioned to take advantage of the scientific opportunities created by human exposure to radiation” (Johnston and Barker 103). There is evidence to suggest that this advantageous position may have been intentionally created by the U.S. officials who neglected to evacuate the Marshallese in the first place, a belief that many Marshallese still hold. In a 2004 speech, Rongelap Major James Matayoshi questioned the accidental nature of the exposure. Even before Operation Bravo commenced, the Los Alamos team responsible for the test explosion released a document outlining the desired data to be gathered post-detonation. Included in that list was a proposal for a project called “*Study of Response of Human Beings Exposed to Significant Beta and Gamma Radiation Due to Fall-Out from High Yields Weapons”*, or Project 4.1 (Barker 41). U.S. government officials claim that the document was doctored, retroactively adding the Project 4.1 proposal after the Bravo incident, but many remain unconvinced. Mayor Matayoshi wonders how the U.S. would have been able to get the project up and running, subjects of Project 4.1 were photographed as early as July 16th, if Project 4.1 was not “conceived, planned and funded prior to March 1, 1954.” The potential data to be collected from this test was invaluable in scientific and, perhaps, national defense terms. Little was known about the impact of radiation on human health, particularly over longer periods of time. The radiation that the Japanese were exposed to in the final days of WW II pales in comparison to the doses received by the Marshallese, providing much more useful data about the effects of large doses. The yield of the Hiroshima and Nagasaki detonations combined was about 35 kt, while the Bravo test alone yielded *15,000* kt (Kirchmann and Warner 19).

Following Bravo, Project 4.1 was initiated, although it was now entitled “*Study of Response of Human Beings* Accidentally *Exposed to Significant Fallout Radiation*” (emphasis

added), implying that the exposure was an unfortunate, unforeseen side effect of the Bravo test. Skin burns were examined, blood and urine samples collected and other symptoms monitored. The tests and examinations were performed without consent or explanation, with the primary goal being data collection, not medical treatment. The project concluded that a larger, longer study was needed to accurately assess the health impact on the exposed Marshallese.

One initial conclusion that came out of Project 4.1 was the professional recommendation by Eugene Cronkite, a physician and Project 4.1 researcher, that the exposed Rongelapese not be exposed to any further radiation for at least 12 years, preferably the rest of the their lives due to the intensity of their exposure (Barker 110). The need for more complete data led to the formation of a long-term human subject research program involving the Rongelapese. Included in this project were plans for extensive physical examinations, hematological studies, growth studies of children as well as environmental surveys of the affected islands (Barker 111). Notably missing from this list is a study of reproductive and intergenerational effects, dismissed due to the "personal" nature of the research required. It is hard to believe that these atomic scientists were suddenly struck with a sense of decency and concern with privacy violations. Most researchers believed that the reproductive effects of radiation would be minimal and the complications of keeping track of the samples would be too great to justify the hassle. One physician even questioned the validity of the data considering that "you don't know who the fathers are," an insulting insinuation about Marshallese culture (qtd. in Barker 111). It was for these reasons, rather than a concern for personal privacy, that intergenerational effects were not included in the study, despite an obvious increase in birth defects.

Return to Rongelap

"The levels of radioactivity [on Rongelap] are higher that those found in any other inhabited location in the world. The habitation of those people on the island will afford most valuable ecological radiation data on human beings." *–Dr. Conard, 1957*

Despite Dr. Cronkite's clear recommendation that the exposed islanders avoid any future radiation exposure, the decision was made to return them to their home island in 1957. Once again, researchers were more concerned with what valuable data the Rongelapese might be able to provide than their status as human beings already suffering greatly from radiation sickness. The lack of empathy and concern shown by some physicians, those on whom we rely and entrust our medical care, is disgusting. Here was a unique population, exposed to levels of radiation seen nowhere else in world, and the potential knowledge to be gained was equally unique. As in the case of the development of the first atomic bomb, the lure of the unknown proved too great for some researchers like Dr. Conard, one of the lead medical doctors of the long term study.

In 1955, before the U.S. decided to return the residents of Rongelap to their home, environmental surveys were conducted on the atoll. Many staple crops were found to have Sr^{90} levels exceeding those deemed safe. Perhaps not unsurprisingly, radiation levels were found to be concentrated in lower lying areas, or pits, typically used by natives for planting. Coconut crabs, a commonly consumed item, were found to have the highest Cs^{137} levels of all the specimens sampled. The result of these studies was a recommendation that the Rongelapese avoid eating coconut crabs when returned to their island. In a declassified report published years later, Dr. Robert Conard suggests that "Rongelap remains slightly radioactively contaminated but careful surveys showed the island to be safe for human habitation in the summer of 1957," a somewhat surprising remark considering that at the time no one knew what long term exposure levels were safe for human habitation. The final test before the return of the Rongelapese was a reading of radioactivity taken from 200 feet above ground by plane, data that the U.S. claimed meant radiation levels had indeed subsided and the island was once again habitable. One critic lamented the lack of adequate radiological assessment, noting that he "had assumed there would

be another radiological survey of the Rongelap atoll just prior to the return of the Rongelapese. … It would have been highly preferable to have had a complete survey of the atoll, especially the foodstuffs, but it appears we will have to settle for external readings only" (Gordon Dunning, qtd. in Barker 114-5). It is unclear whether this is simply lazy science or this was a downright irresponsible, intentionally misleading survey, although the latter seems more likely. U.S. officials would have had a large incentive to declare the land habitable to move the displaced islanders back home. The longer the Marshallese were kept from their home islands, the more public pressure there was to return them home safely. Also, from a research perspective, the faster they were returned, the sooner data could be gathered. It seems hard to believe that any scientist would have honestly trusted an air reading as indicative of conditions on the land. Either way, it is apparent that conducting an accurate assessment of the radiological conditions on Rongelap was not of prime importance.

Additionally, it is absurd that scientists were even arguing about the finer details of environmental testing when it was already made clear by earlier researchers that by no means should the exposed islanders be exposed to ANY amount of radiation for 12 years. The fact that soil tests had showed elevated Sr^{90} and Cs^{137} around the island should have been enough for scientists to definitively determine that the safe return of the residents of Rongelap was not a viable option. It is unclear where the chain of command went wrong. Cronkite's 1954 report about the dangers of exposing the population to further radiation appears to have been ignored entirely. Disregarding Cronkite's medical recommendation, a 1955 environmental report suggested that the return to Rongelap occur "as soon as rehabilitation procedures are completed, with the advice that land crabs not be eaten at this time" (Dunning 50-51). There appears to be a disconnect here between the medical and environmental reports published, two fields which are

inextricably linked and consequently cannot be considered independently when making public health decisions. The 1957 announcement that Rongelap was indeed safe was based on the inaccurate declaration that radiation levels had subsided by comparing 1955 soil reports with the 1957 aerial reading.

Politics and global opinion of the U.S. were also important factors in the decision making process. The AEC Advisory Committee on Biology and Medicine (ACBM, 1957) pointed out that "the current low morale of the natives … and advantages of returning them to their homes presented as a factor which should be balanced against the possible radiation hazard in their return." Considering that scientists could not even concur on a suggested plan of action, it is no surprise that government officials chose the option that suited their interests best. Having an exposed population living in a contaminated environment would provide a unique opportunity to gather valuable data about the impact of radiation on people. The ACBM was also of the opinion "that if it should be necessary to re-evaluate because of further tests there would result world opinion unfavorable to the continuation of weapons testing'," making the 1957 decision to return the residents of Rongelap almost irreversible. Already concerned about public opinion following the media's portrayal of the Bravo detonation, government officials worried about a potential UN ban on weapons testing if protests escalated. With discontent growing, it is not unreasonable that the U.S. government would want to return the displaced Marshallese as soon as possible. This only became problematic when the U.S. decided in 1957 to relocate people to islands containing questionable levels of radiation, making a dangerous commitment without adequate data on current radiation levels or the potential health hazards.

Human Research Subjects

"There was no informed consent; for four decades, the Marshallese … were human subjects in a nuclear science program that was about body parts—thyroids, eyes, bone marrow, blood, and urine—not whole human beings, without knowing they were experimental subjects" *–Laura Nader and Hugh Gusterson, in Half-Lives, 2004*

Once returned to their home on Rongelap and Utirik, another previously evacuated northern atoll, the U.S. government initiated long-term medical examination and treatment program involving the exposed Marshallese. Beginning in 1956, Dr. Conard and his team from Brookhaven National Laboratory (BNL) conducted exams of the Rongelapese annually and once every three years of residents from Utirik. Medical findings from this study were based largely on a comparison with a control group of 150 "unexposed" Marshallese. Unfortunately, the unexposed group was comprised of individuals who were not present on Rongelap or Utirik at the time of the Bravo test, but moved back 1958 when the land was declared habitable (Johnston and Barker 219). This meant that although they were spared from the initial contamination, they were equally exposed to the residual radiation left from the testing along with the "exposed" group. As a result, many of the subjects from both groups of the study exhibited similar symptoms, including thyroid abnormalities, nodules and cancer. From this, scientists concluded:

> "During the ensuing decade the people remained as healthy as the population of unexposed Rongelap people used as a control group (about 200) with no further evidence of radiation effects, except an increase in miscarriages and stillbirths in exposed women which is questionably related to exposure." (Conard, 1978:2)

This was a grave and inexcusable error of both judgment and analysis, considering scientists should be familiar with the fundamentals of research design. The classification of secondarily exposed people as constitutional of an "unexposed" population is inexcusably bad science that allowed scientists to come to false conclusions. All participants were living on

Rongelap or Utirik and were consequently exposed to the same radiation in the soil, plants and other consumables. A more accurate comparison study should have involved Marshallese citizens living on islands outside of the recognized contamination limits. No data from this study can, or should, be used as criteria for assessing the health impacts of the nuclear tests.

Unfortunately, that is exactly what happened. This 1978 study is often used to absolve the bombs of any responsibility for over half a century of health problems in the Marshall Islands, including elevated cancer rates and an increased number of severe birth deformities (Johnston and Barker 218). Many of these birth deformities are particularly gruesome, with Almira Matayoshi describing her experience as "[giving] birth to something that was like grapes" (qtd. in Barker 15). Between 1954 and 1958 one out of three children born died at, or shortly after birth, due to a variety of horrible deformities. While no medical tests were performed before the nuclear test program began, it is clear through interviews with local mothers that these kinds of births were unheard of before the testing. It is also hard to believe that deformities like this could have been common in a naturally thriving population. The pain of these births extends beyond the physical and into the emotional and psychological realm. There is great shame and social stigmatization associated with giving birth to a "thing" instead of a normally developed, healthy baby. In Marshallese society, birth abnormalities are generally interpreted as a sign of some wrongdoing of the mother, often infidelity. This is but one of the effects overlooked by researchers concerned primarily with physical health measures. Sadly, the lack of legitimate comparative studies has limited the ability of many Marshallese to get the U.S. government to recognize their injuries and conditions as resulting from the nuclear testing. Receiving proper, just compensation has been a continuous struggle, one that still holds the U.S. and the RMI locked in an ongoing battle.

Chapter IV. The Attempt at Amends

Compact of Free Association

"The fact that anyone was injured by recent nuclear tests in the Pacific has caused the American people genuine and deep regret. (…) it can be categorically stated that no stone will be left unturned to safeguard the present and future well-being of the Islanders." *–Mason Sears, U.S. representative in a statement to the Trustee Council, 1954*

From the start, the Marshallese have expressed deep concerns about the impact of the U.S. nuclear test program on their nation. Following the Bravo test in 1954, the Marshallese government petitioned the UN about the lack of protection islanders were receiving as a U.S. Trust Territory. Worried particularly about their health and loss of land, the Marshallese were reassured by both the UN and U.S. government that their needs would be taken care of and that they would eventually be returned home. Urging by the international community led to the premature return of the Rongelapese, with little regard to ensuring that other needs, like a *safe* homeland, were met. More easily said than done, the reassuring statements, like the one from Representative Sears above, remained empty promises until put into legislation as part of the 1986 Compact of Free Association between the U.S. and the RMI. U.S. responsibility and reparation offerings are outlined in section 177 of the compact, which is devoted entirely to the nuclear legacy of U.S. Cold War testing. Section 177 includes a $150 million settlement to the RMI government to create a trust fund for all claims, past, present and future, related to the U.S. testing program. Additionally, a Nuclear Claims Tribunal was created to adjudicate claims and dole out settlement payments to eligible parties. The Compact also contains an acknowledgement that in the biomedical research conducted following the testing there may have been "some tension between data gathering and patient care," a diplomatic admission that the scientific knowledge gained was at times put ahead of the best interests of the Marshallese (ACHRE Final Report 585).

More importantly, Section 177 also includes a "changed circumstances" clause which allows the Marshallese government to petition the U.S. for more money should new information arise post-compact agreement. This clause requires first that the RMI demonstrate that new data about the effects of the test program exist. It must then be proven that this information was not known at the time of the compact negotiations and that the compensation already provided in the compact is inadequate considering the new circumstances. Only once these conditions are met can the Marshallese petition for additional aid.

Claiming Changed Circumstances

"From recently declassified information and independent scientific and medical research, the RMI government knows that radiation from the U.S. government's weapons tests caused substantially greater injury to people and land than was previously known or made public." *–Dr. Holly Barker, 2004*

Considering the lack of data that existed regarding radiation, especially its inter-generational effects, the changed circumstances clause seems a well-considered addition. In spirit, the law acknowledges a reasonable amount of uncertainty in the 1986 settlement and allows for future flexibility should new information arise. In practice, proving that circumstances have indeed changed has been extremely difficult. The RMI submitted a changed circumstances petition to Congress in 2000, claiming that new information regarding radiation exposure had come to light. The petition claims that these changes in available data prove that the current funding is "manifestly inadequate" and, therefore, requests additional compensation for affected Marshallese. Included in this are funds for personal injury claims, property claims, to improve health care and to extend monitoring programs to other atolls beyond the four that were recognized as "affected" in the initial agreement. This last point has been a source of contention since the initial signing of the Compact. Only Marshallese residing on one of the four atolls designated by the Compact as impacted by the testing may petition for assistance. This

initial designation was based on the belief in 1986 that radiation levels were too low to cause any adverse health effects on any of the other atolls or islands. At the time, the maximum dosage considered "safe" exposure was 500 mrem per person, per year. Today, the EPA acknowledges 15 mrem as the standard for anthropogenic radiation sources (Barker, "Half-Lives" 240). Also excluded are government workers, soldiers, and sailors who were responsible for cleaning and preparing the contaminated atolls for resettlement. The migratory nature of Marshallese society is neglected, meaning that the number of people who were undoubtedly exposed is far larger than the Compact acknowledges. A 1987 study showed that a relatively high prevalence of thyroid nodules and abnormalities were found on other "unexposed" atolls, including Likiep, Wotje, Lae, Ujae and Wotho (Hamilton *et al.*). They also found that the frequency of thyroid nodules was proportionally correlated with distance from Bikini atoll, suggesting testing conducted there may be responsible. These data were not available at the time of the signing of the Compact in 1986.

Since 1986, additional documents have surfaced concerning the extent of the radioactive fallout. A document belonging to the Biological Medical Division of the U.S. Atomic Energy Commission declassified in 2003 contains an updated map of the fallout from the 1954 Bravo test. Unlike maps released shortly after the detonation, which show the initial contamination, this map accounts for additional settling and accumulation of radioactive fallout (Figure 8). The extent of the fallout is much larger than older maps suggest. For example, earlier maps place Rongerik Atoll in the 200 R range of contamination (1 R= 1 rem= unit of ionizing radiation equal to the dosage that will cause the same biological effect as one roentgen of x-ray or gamma-ray radiation). On this map, Rongerik falls on the cusp between 1000 R and 300 R. This map is another example of the information lacking in 1986.

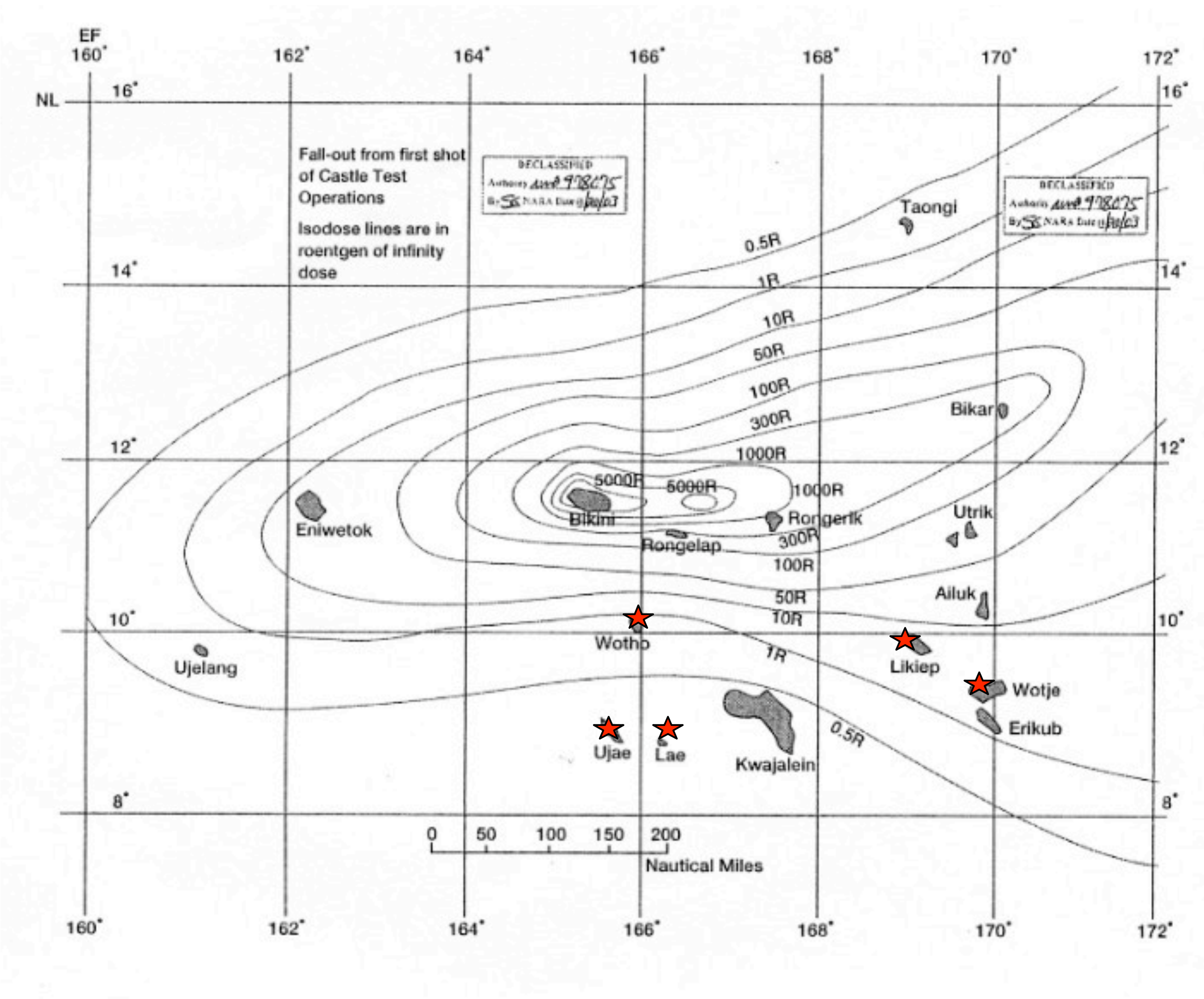

Figure 8. Map of Bravo Fallout (U.S. National Archives, declassified in 2003). Red stars indicate atolls home to a higher frequency of thyroid nodules in 1987 study by Hamilton, *et al*.

At the time of Compact negotiations, little information was available to the Marshallese to accurately determine the extent of the exposure and consequently what constitutes just compensation. All decisions made by the RMI at the time were based on data provided by the U.S. government as no independent scientific assessments were conducted (Barker 115). One of the basic necessities of sound policy making is adequate, unbiased data, which did not exist in 1986. The Marshallese had no way of verifying the information fed to them by the U.S. government, making it easy for the U.S. to manipulate the negotiations. Far from perfect, the

agreement was the best the Marshallese could hope for at the time. With many documents still classified in the name of national security, access to complete and accurate data remained difficult throughout the remainder of the twentieth century. It is only in the last two decades that the full extent of U.S. nuclear testing programs has come to light. Much of this declassification is a result of a 1994 advisory committee established by President Clinton to investigate the U.S. government's role in human radiation experimentation. The Advisory Committee on Human Radiation Experiments (ACHRE) led to the declassification of massive amounts of information pertaining to U.S. nuclear testing. An analysis of this wealth of new data paints a very different, and unflattering, picture of the U.S. presence in the South Pacific during the latter half of the twentieth century.

Updating an Outdated Compact

"Can I be completely honest? Well, I'm going to be completely honest. Being out there (RMI) for 2 years, what I sensed is that we really neglected this area of the world. And whereas we have a compact, there wasn't enough attention, there wasn't enough assistance." *–Diane Watson, Congressional Hearing, 2007*

As a result of the RMI government's ongoing petitioning, the Compact was amended in 2003 and an additional $1.5 billion was allocated for distribution to the RMI over the next 20 years. Thus far, this funding has been used to improve infrastructure, education and health care. Little of the money has been used for any sort of environmental clean up program, an expensive and complicated undertaking. The amended Compact also calls for increasing deposits into the Trust Fund for the People of the Marshall Islands in the hopes of generating a source of financial support when grant assistance ends in 2023.

In 2007, a congressional hearing was held to assess the current state of the Marshall Islands and determine whether or not the changes made in 2003 were adequate. Many cited the

increased funding and the improvement of Marshallese infrastructure as proof that the funds were indeed accomplishing their goal. However, there is still debate over whether or not this is enough. In his opening statement to Congress, Gerald Zackios, Foreign Minister of the RMI, declares that:

> The U.S. Government must update its antiquated policies on the scope of radiation damage and injury. Currently, the United States Government employs science and standards of radiation knowledge from the 1970s and 1980s. Healthcare and environmental programs in the Republic of the Marshall Islands need to incorporate decades of new knowledge that demonstrates that smaller amounts of radiation do more harm than previously understood, and that damages and injuries are not confined to the four atolls or the result of just the Bravo event. (Congressional Hearing, 2007: 29)

In this statement, he highlights how information available today should be enough to warrant the increases in funding for which he is petitioning. On behalf of the Marshallese government, he calls for "stable and permanent" funding as opposed to the discretionary funds that have been allocated over the years. This "Band-Aid" approach, as he calls it, does little to address the ongoing need of the Marshall Islands to establish an adequate, self-sustaining health care system. Not only are people dying of radiation induced cancers, but additional thyroid conditions continue to plague a population with little ability to treat them. The lack of acknowledgement of the full scope of the testing program's impact continues to severely limit the assistance that many Marshallese receive.

Zackios also asks for an improvement in environmental monitoring and remediation on all affected islands, not just Rongelap and Bikini. Consistent throughout the Marshallese

argument is the assertion that the scope of damage is far beyond initial reports suggested. Eni Faleomaveaga, chairman of the Congressional Subcommittee on Asia, the Pacific, and the Global Environment, expressed his distress about the lack of significant improvements on policy with this new information:

> They have just declassified some documents and found out that the entire island group of the Marshall Islands was exposed to serious nuclear radiation. And guess what? We have not done anything to address this declassification of how we went about in making these examinations of human beings who were exposed as a result of our nuclear testing program. (Congressional Hearing, 2007:20)

Also distressing is the comparative aid provided to populations in the southwest U.S. affected by the Nevada nuclear testing. Despite the fact that the total yield of all tests performed at the Nevada test site is only equal to **one percent** of that from the Marshall Islands testing, the geographic area recognized as affected is much greater in the American southwest. Another interesting comparison is the $2 *billion* is awarded annually to the cleanup of the Hanford nuclear production site in Washington state compared to the $4 *million* the U.S. has paid for property damages in the RMI out of the $1.1 billion that is owed (Barker, “Half-Lives” 241). Additionally, at Hanford, the cleanup goal is set at the national standard of 15 mrem, much lower than the international standard of 100 mrem that the U.S. government maintains is sufficient for the RMI. There appears to be no reason for this disparity other than unwillingness on the part of the U.S. government to apply the same standards of safety to our soil and the soil of what was a U.S. Trust Territory at the time. Based on our knowledge of radiation today, these standards simply do not make sense and must be changed.

V. Conclusions

"History- even the history of science- is inherently about people, how they thought, what they did with their thoughts, and how they interacted with the individuals immediately around them and then with society and the greater world order." *–Diana Preston, 2005*

"After 15 years of investigating, I have concluded that the US government's atomic weapons industry knowingly and willingly recklessly exposed millions of people to dangerous levels of radiation. … Nothing in our past compares to the official deceit and lying that took place in order to protect the nuclear industry. In the name of national security, politicians and bureaucrats ran roughshod over democracy and morality. Ultimately, the Cold Warriors were willing to sacrifice their own people in their zeal to beat the Russians. *–Stewart Udall, 1994*

The troubling situation in the Marshall Islands was not created overnight. The story begins long before Operation Crossroads, even before the first atomic bomb was dropped in New Mexico in July of 1945. Beginning with the establishment of the Manhattan Project in 1942, the world was set on course for what would become a tragic saga of nuclear devastation. Although the earth has not been destroyed by nuclear war, humanity has still suffered as a result of "peaceful" detonations. The development of a large scale nuclear testing program in the years following WW II was a result of the anxiety-ridden political climate of the day, one which allowed little room for dissenting voices. In many cases, the costs of speaking out against government policy were too great, leading to dangerous propagation of nuclear research programs responsible for the state in which the Marshall Islands remains today.

Following the deployment of the atomic bomb in Japan in August of 1945, many scientists involved in its development were distraught with what they had created. In fall of 1945, Oppenheimer believed that the scientists of the Manhattan Project had "made a thing that by all standards of the world we grew up in is an evil thing" (qtd. in Schweber 17). Before the bomb was put into action, despite some doubts, most scientists supported the research as part of the inevitable drive towards progress. No one predicted the magnitude of devastation that was to be unleashed on Hiroshima and Nagasaki. It wasn't until after scientists were "pushed out of

their complacency by images of nuclear destruction" that they truly grasped the horror of the fruits of their labor (Wang 13). They were not alone in these concerns. British Prime Minister Winston Churchill reflected that "this revelation of the secrets of nature, long mercifully withheld from man, should arouse the most solemn reflections of the mind and conscience of every human being capable of comprehension" (qtd. in Preston 2).

There is no question that many had doubts about the continuation of nuclear weapons development after Japanese surrender in August of 1945. In the fall of that same year, Szilard circulated a petition amongst atomic scientists, urging President Truman to consider the moral responsibilities that come with building nuclear weapons (Rhodes 749). A collection of scientists formerly involved in the development of the bomb began to unite in their concern for the future of nuclear technology, forming what has been subsequently dubbed "the atomic scientists' movement". These scientists wrestled with tough questions concerning the role of science in society and the "evolving political economy of postwar America" (Wang 3). Many of these scientists protested the May-Johnston bill, put forth in October of 1945, which subjected all atomic energy research to strict security regulations and complete military control, on the grounds that it would quell all hopes of "international cooperation on peaceful uses of atomic energy, and the development of international control schemes" (Wang 14). Scientists worried that if the U.S. continued to focus solely on the military uses of atomic energy, and draft policy accordingly, that the rest of the world would become increasingly suspicious of U.S. motives, a trend that would have devastating consequences when the U.S. inevitably lost its nuclear monopoly. In the eyes of many scientists, only through a policy of openness and international cooperation not one designed with the aim of generating a bigger, better pile of nuclear weapons could peace be achieved.

Unfortunately, their ideas of international scientific cooperation and the abolition of atomic secrets did not jive with the prevailing anti-Communist ideology of the Cold War. To government agencies like Federal Bureau of Investigation (FBI) and The House Un-American Activities Committee (HUAC), "the scientists' internationalist agenda symbolized a dangerous naiveté about Soviet intentions, or even worse, an open preference for the Soviet Union over the United States" (Wang 44). By the late 1940s, scientists began to find not only their ideas, but their loyalties to the U.S. were under internal scrutiny. Representative J. Parnell Thomas, a member of HUAC, perhaps provides a more accurate assessment of the scientists' motives and offers his criticism:

> I do not say that these one-world-minded persons are unpatriotic. I say that their intense ardor for a better world has blinded them. (…) when they advocate a free exchange of atomic secrets with Russian scientists, they completely overlook the fact that all Russian scientists are but tools in a dictatorship of the proletariat. (qtd. in Wang 1999: 48)

Thomas' views exemplify how many politicians viewed scientists at the time: "starry-eyed individuals" who are best left out of decisions regarding national security. Many scientists, including Oppenheimer, lamented the lack of political change they could affect, justifiably feeling as if their concerns went unheard by government officials. James Franck, a physicist driven from Nazi Germany during the war, sums up the problem, wondering:

> How is it possible that the statesmen are not informed that the aspect of the world and its future is entirely changed by the knowledge that atomic energy can be tapped, and how is it possible that the men who know these facts are prevented from informing the statesmen about the situation? (qtd. in Smith, 1965: 32)

This uncommunicative relationship between politics and science became especially problematic with the advent of the atomic age. Viewing science as a practice independent of the political atmosphere is to place the actions of a scientist, including what research he or she chooses to pursue, in a vacuum. This is not a particularly useful approach if one seeks to understand how and why nuclear development and test programs flourished in the postwar years. The decision of some scientists to remain committed to this program was often a result of the false belief that science can in fact be separated from politics. John W. Gofman, former Manhattan Project physicist and staunch anti-nuclear power advocate, provides a useful anecdote. In talking with a fellow scientist at the Livermore Weapons Laboratory about the separation of politics and science, his colleague commented that it is “the job of scientists at a weapons laboratory was to make the best nuclear weapons, and to leave to the politicians and statesmen the questions of *use* of such weapons.” In response, Gofman suggested that “if the politicians asked the Laboratory to come up with best design of gas chambers, the Laboratory and others like it would vie with each other for the contract avidly. Their answer was that I was ‘exaggerating’” (154).

This example illustrates an alarming attitude of some scientists while also highlighting another issue. Especially in a time of war, it is easy for research agendas to be swayed by political, or military, needs. War is often a strong driver of technological advancement, blurring the lines of pure and applied science. The wartime mentality can easily hijack pure science, allowing research to proceed if and only if it is conducted with the aim of serving some military goal. The Cold War is no exception. “Pure” atomic science, or research conducted for the sole purpose of furthering general knowledge, no longer existed. The U.S. government’s research agenda bound atomic discovery with its applications in weapons production. This is one of the

primary reasons why so Szilard, among others, fought so hard for civilian control over atomic research. With the government controlling atomic science, avenues of research were limited.

The regulation of science is an interesting issue. While most would agree that the development of gas chamber technology has crossed the line, it is difficult to discern where the line actually is. Additionally, who determines where the line is drawn is a tough question to answer. While it seems reasonable that each individual scientist should decide what research they feel comfortable conducting, the problem with this method is two-fold. Firstly, not everyone feels the same social or moral obligations. There certainly are scientists, along with members of all professions, who have "insatiable appetites for power," and are primarily out for money and prestige, as Gofman suggests (187). As he says of "sycophants" in the employ of powerful pro-nuclear energy politicians, "no matter how dirty the job, there will be some well-educated, well-mannered, slick if not positively slimey creature, complete with credentials, out there somewhere available for hire" (173). However, this view implies that those who continued with nuclear research programs had some great moral failing, which although likely true of some, is a gross oversimplification. Gofman seems to fall prey to his argument, neglecting to give credit to the political pressures of the day and the very real threat of having one's life destroyed with an accusation of communist activity.

Oppenheimer counters Gofman's accusation, summing up what he believes to be the mantra of a true scientist:

> If you are a scientist, you believe that it is good to find out how the world works; that it is good to find out what the realities are; that it is good to turn over to mankind at large the greatest possible power to control the world and to deal with it according to its lights and values.
> (qtd. in Preston, 2005: 339)

Here Oppenheimer gets at the central motivation of atomic science and scientific inquiry in general. Once the idea of atomic energy was proven feasible, many scientists felt the inevitable pull to push the limits of the current knowledge of physics, embracing the challenge of fully developing this technology. This does not make them "slimey creatures" but rather the embodiment of the principles which drive science. Making knowable this unknown was a fascinating line of inquiry and many felt scientists felt that it was not their concern to be diverted by considering future applications of this knowledge.

In theory, this argument makes sense, but this is too compartmentalized of an approach. Oppenheimer intentionally neglects to address the issue of what to do with the knowledge gained through scientific pursuit. The notion of "turning it over to mankind" implies a separation between scientists and the rest of the world, a division that does not exist. Scientists are citizens too, bearing the same responsibility as the rest of society.

Social critic Dwight Macdonald also attempts to answer the question of how scientists allowed themselves to build the first bomb. He claims that the problem lay in their self-designation as "specialists, technicians and not as complete men… in the sense that the process of scientific discovery is considered to be morally neutral," a description that seems to fit Oppenheimer's logic (Macdonald 85). This ability to conduct research without thinking of future consequences was a notion shattered by nuclear technology, which had the potential to create devastation of unprecedented magnitude. The experiences of Hiroshima and Nagasaki made this a reality.

As the Cold War began to escalate in the early 1950s, scientists were increasingly under attack, with accusations of disloyalty intensifying. Actions that may have previously been written off as idealistic and uneducated were now regarded as subversive. J. Edgar Hoover, the

oft-overzealous director of the FBI, viewed anyone advocating for the free exchange of scientific knowledge as under "Communist influence," and worthy of further surveillance. Problematically, the FBI and HUAC were not particularly good, or interested in, distinguishing between real and imaginary threats. Scientists often found themselves in a precarious position: speak out against the government's nuclear weapon policy, risking both career and reputation, or remain quiet and aid in the continued research effort. The consequences of speaking out could be severe, as Oppenheimer experienced when he publicly objected to the development of the hydrogen bomb and lost his security clearances as a result. He was not only under attack by the anti-Communist rage of government officials, but even by other scientists. Edward Teller, Oppenheimer's colleague and fellow physicist, testified against Oppenheimer at the 1954 AEC hearing, suggesting his opposition was indeed an indication of his lack of patriotism (Preston 318). This led many scientists to retreat, afraid to speak out for fear of meeting a similar fate. There was simply no room in atomic research for those whose opinions did not fit into government policy and ideology.

A related, but slightly different, problem that science faced was the unprecedented preoccupation with secrecy and security. Scientists given special security clearances during work on the Manhattan Project found themselves somewhat trapped by the knowledge they had acquired. Most expected the restrictions placed on their work and communication during wartime were to lift somewhat with the end of WW II. Instead, they found themselves "custodians of secrets on which the whole national life might depend," a burden that came with a lifetime commitment to secrecy (Wiener 109). Already privy to atomic secrets, in a sense, there was no turning back. Research options available to those interested in atomic science were limited to the narrow range of military directed projects.

Although the role of political factors should not be downplayed, it is important not to neglect the free agency of scientists. A discussion of the influence of the Cold War environment on dissenting scientists assumes first and foremost that the scientists were in fact opposed to the research programs instituted in the postwar years. This was not always the case. Gofman makes a brief allusion to this, explaining that they can "get carried away with the elegance of their scientific and technical insights, which are undeniably clever. *Often* I have head them refer to a bomb-design as "neat," and even more often as "sweet," echoing Oppenheimer's testimony at his 1954 trial that "when you see something that is technically sweet, you go ahead and do it" (USAEC). This is a larger part of the problem than many historians of the atomic age seem to admit. There were some scientists who appeared to have no qualms with the research agenda, especially some of those involved in the Marshall Islands test program. One such person is Merril Eisenbud, the environmental scientist who served the director of the Atomic Energy Commission from 1947-57 during the height of the nuclear testing in the Marshall Islands. In regards to the radiation exposure received by many islanders from the Bravo test, and their subsequent relocation on contaminated islands, Eisenbud offers this:

> Now that island (Utirik Atoll) is safe to live on but is by far the most contaminated place in the world and it will be very interesting to go back and get good environmental data … so as to get a measure of the human uptake when people live in a contaminated environment. Now, data of this type has never been available. While it is true that these people do not live, I would say, as Westerners do, civilized people, it is nevertheless true that these people are more like us than mice. (ACBM 1956: 232 in Johnston, 2004)

This certainly does not sound like the voice of an unwilling researcher. With undisguised racism, Eisenbud does not appear to be concerned in the slightest about the experimentation on human subjects. The U.S. government's interest in this question is clear: they wanted to know what would happen to people exposed to a nuclear attack. Unfortunately, by definition, human subjects were needed to answer this question. Whether or not this could ever be conducted ethically is questionable. Also questionable is how scientists like Eisenbud and Conard, the researcher in charge of the long term study initiated on the Rongelapese, could in good conscience conduct this research. Clearly dehumanization played a part, as made clear by Eisenbud's "more like us than mice" comment, which helps account for why this testing was not conducted instead on U.S. soil. This designation of "otherness", frankly racism, also played a part in the decision to drop the bombs on Hiroshima and Nagasaki: new islands, same logic. What makes the case of the Marshall Islands all the more tragic is that they were never an enemy state, but a *Trust Territory* of the U.S. The thought that some scientists willingly pursued research agendas that jeopardized the health and well being of fellow human beings is appalling.

Without the passion of discovery, scientific progress would stagnate. At the same time, singular passion can blind scientists to the moral dilemmas associated with their pursuits. In the case of the atomic bomb, probing into the very nature of the building block of life became too alluring for scientists to step back and consider the implications of their work. Similarly, when it came to nuclear testing in the Marshall Islands, the desire to learn more about this bomb functioned and the impact it had on humans and their environment was equally appealing. This unchecked curiosity led to devastation. In the end, the benefits of the knowledge gained were, debatably, outweighed by the human costs. Perhaps some mysteries are better left unsolved, for not all scientific knowledge can be called progress.

Edward Teller would disagree with this statement, stating in a 1994 interview that "there is no case where ignorance should be pursued to knowledge- especially if the knowledge is terrible." While Teller seems to echo Oppenheimer's earlier beliefs, the fundamental difference between the two scientists was the eventual admission by Oppenheimer, in his opposition the H-bomb, that there were moral constraints on what work a scientist should pursue. Teller never had a similar revelation.

One of the biggest challenges is in reconciling the driver of scientific inquiry, Teller's well-articulated curiosity about the unknown, with the real-world implications of the potential knowledge to be gained. One cannot evaluate science in a void, either when judging previous actions of scientists or when making future decisions. The researchers of the Cold War era were living in an environment that was inherently incompatible with the principles of science. The free exchange of ideas and open debate are essential to the advancement of scientific knowledge, for without discourse between scientists, the rigor of proof is lost. Educated debate over ideas and theories, along with their consequences, prevent unchecked research from running free. When this communication is stifled, the results can be disastrous, like in the case of the U.S. nuclear test program. Any scientist that dare speak out against the acceleration of the testing program was effectively removed from the system. Instead of the scientists directing the research, the U.S. government allowed the research to direct the scientists, pruning researchers that raised objections. This is a dangerous and troubling way to conduct science. Conditions like these are what led to the development of programs like Project 4.1 where Marshallese citizens were subjected to unethical and sometimes dangerous research regimens. By silencing and removing all protesters, the only ones left were those who were too tempted by the "sweet" aspects of the research, or valued their careers more highly than their moral obligations.

The history of atomic science is anything but straightforward. Finding the delicate balance of accountability between politicians, researchers and global conditions is difficult considering all of the factors involved. As historian Jessica Wang suggests, scientists were "simultaneously partially responsible for but also subject to the ideological constraints of the post-war era" (4). The well-acknowledged influence of Cold War political ideology on research agendas, namely one of suppression and censorship, is not the only way that science and politics interacted. As made clear by comments of researchers like Dr. Conard and Dr. Eisenbud, not all scientists were unwilling and therefore must be held accountable for their actions. It is true that the Cold War era was a difficult time for many scientists, but it was also an exciting time for many, an attitude which cannot be dismissed. Scientists are too often cast as simply victims of the climate, but this is not a fair assessment. While some, like Oppenheimer, did eventually speak out, others scientists continued to conduct research, claiming immunity from the responsibility of the implications of their work. Teller continued to believe that "whatever the scientists are able to discover (…) the people will be good enough and wise enough to control it for the ultimate benefit of everyone" (Teller 274). The problem with this attitude is that it refers to a fictitious group, "the people," on whose shoulders all responsibility is placed. It excludes the scientists, who are also citizens with civic duties, from collective responsibility. If anything, those with technical knowledge owe it to the rest of the society to carefully consider the ramifications of their work. Science cannot be considered independent of its potential implications, a lesson that will hopefully be heeded in coming years, for the sake of all humankind.

Acknowledgements

First, I would like to thank Professor Rick Hazlett who provided the initial inspiration to undertake this thesis. I am very thankful for your willingness to help brainstorm, even in late August while on sabbatical! I would also like to thank Professor Chuck Taylor for generously agreeing to serve as one of my readers for this thesis. Your feedback, especially your fine attention to detail, was a great help! Lastly, I want to give Professor Char Miller a *huge* thank you for not only all of his help with the physical writing of this thesis, but also for the emotional support and encouragement provided along the way. From the first day when I came to your office with the vaguest outline of a huge topic (read: "I want to do something about nuclear testing in the South Pacific"), you were always there to ask the right questions and guide me on my way. Your constant support and feedback though this entire process has been invaluable. I can't imagine navigating this process without you! Thank you so much.

When you write things down, they sometimes take you places you hadn't planned.

-M. Benjamin

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