Mutant Ecologies: Radioactive Life in Post–Cold War New Mexico

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> It is a curious phenomenon of nature that only two species practice the art of war—men and ants.
>
> —Norman Cousins, *Modern Man is Obsolete* (1945)

> A full-scale nuclear attack on the United States would devastate the natural environment on a scale unknown since early geological times, when, in response to natural catastrophes whose nature has not been determined, sudden mass extinctions of species and whole ecosystems occurred all over the earth. . . It appears that at the outset the United States would be a republic of insects and grass.
>
> —Jonathan Schell, *The Fate of the Earth* (1982)

In the classic Hollywood science fiction film, *Them!* (Douglas 1954), Los Alamos weapons science and Cold War logics of "containment" are both turned quite sensationally on their heads. Rather than producing international security in the form of a military nuclear deterrent, the American nuclear complex is portrayed as the domestic source of proliferating radiation effects, creating an entirely new ecology of risk in the form of gigantic mutant carnivorous ants. The film identifies these fantastic creatures as the product of the first atomic explosion conducted in New Mexico by Los Alamos scientists on July 16, 1945. In the film, the Trinity Test appears not as a triumph of American big science, or as the technoscientific means of ending World War II, or as the military foundation of the world's first nuclear superpower. Rather, the first atomic explosion, in this science fiction, appears as the source of an inverted natural order, in which the smallest of creatures can become a totalizing threat, requiring a total mobilization of the security state to protect citizens from the unintended consequences of Los Alamos science. *Them!* articulates a new kind of nuclear fear in 1954, not one based on the apocalypse of nuclear war but on the everyday transformation of self and nature within an irradiated landscape. Remembered today mostly for its McCarthy-era theatrics in

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which the giant ants figure as a thinly veiled allegory for the communist "menace," the film more subtly presents a devastating critique of U.S. nuclear policy at the very height of the Cold War: It argues that with the first nuclear explosion on July 16, 1945, Americans entered a postnuclear environment of their own invention. From this perspective, the nuclear apocalypse is not in the future—a thing to be endlessly deterred through nuclear weapons and international relations—it is already here, being played out in the unpredictable movement of radioactive materials moving through bodies and biosphere.

Them! is the cinematic instantiation of a larger cultural discourse in the United States about the bomb, in which nuclear critics have deployed insects as a means of engaging the philosophical status of the nuclear age. From Norman Cousins's 1945 essay "Modern Man is Obsolete," written days after the atomic bombings of Hiroshima and Nagasaki, to Jonathan Schell's 1982 portrayal of a postnuclear American republic of "insects and grass," insects have been used to articulate a species logic in relation to a nuclear state of being. The "nature" of nature is interrogated in these discourses, as the power of atomic energy, the "purity" of ecosystems, and the adaptability of certain organisms to a radioactive environment are positioned against human "nature." Cousins's argument that only "men and ants" make war asks if it is a biological imperative to organize conflict in both species (as highly organized but ultimately mindless beasts). Alternatively, Schell argues that humans are too fragile a species to survive a nuclear war, claiming that the only victors would be the insects capable of withstanding and adapting to a radioactive environment. Both authors argue that the destructive power of the bomb demands social evolution, and they deploy insects as a critical mirror to humanity. Technoscience militarizes nature in these discourses, making social evolution and biological extinction the dual focal points of a new kind of modernity (see Russell 2001). In other words, the atomic bomb produces not only new understandings of self, nature, and society but also (as *Them!* argues) initiates a profound mutation in each of these terms.

This article explores the production of nuclear natures in New Mexico, arguing that one of the most profound legacies of the Manhattan Project has been to put in motion changes in specific social and biological ecologies that are highly mutable. To understand these new formations I pursue an alternative engagement with nature/culture through a theoretization of "mutation." The value of this term for an anthropology of science is its attentiveness to multigenerational reproduction and the quality of biosocial transformations over time—marked alternatively as injury, improvement, or noise. My argument proceeds in three parts: First, I examine nuclear injuries produced during the Cold War nuclear testing program, looking specifically at radiation experiments on living beings; second, I explore post–Cold War efforts to reinscript specific radioactive environments as ecological "improvements"; and finally, I interrogate how the concept of a "nuclear worker" has expanded to link humans and wildlife within a shared genetic experiment in northern New Mexico, producing a highly ambiguous and charged social space. Ethnographic attention to the specific terms informing a "mutant ecology," I argue, ultimately allows a productive exploration of the linkages between natures, politics, and futures while recognizing the specificity of place within a nonetheless global nuclear biosphere.

Radioactive Mutants

Them! arrived on American movie screens in June of 1954, just three months after Los Alamos scientists conducted the largest thermonuclear explosion of the Cold War at Bikini Atoll in the Marshall Islands. Detonating with 2.5 times its expected force, Bravo produced a 15-megaton yield and atmospheric fallout that contaminated 50 thousand square miles of the Pacific with "serious to lethal levels of radioactivity" (Weisgall 1994:305; see also Hanson 1988:65). Among the exposed were 223 indigenous residents of Rongerik, Rongelap, Ailinginae, and Utirik atolls as well as the 23-member crew of The Lucky Dragon, a Japanese fishing boat. As American theatergoers flocked to *Them!* in the summer of 1954, making it one of the most successful films of the year, news reports were simultaneously following the progression of radiation sickness among the Marshall Islanders and the Lucky Dragon crew—educating many Americans, for the first time, to the biological effects of radioactive fallout.[1] This graphic documentation of the ecological costs of nuclear testing, as cinematic fantasy as well as brute reality, worked to transform America's nuclear program for many individuals from an exclusively military project to a global environmental threat. After Bravo, the American public began to recognize the bomb not only as a weapon directed at enemy states but also, in the form of fallout, as a chemical and biological hazard at home, challenging the nature of the "experiment" being conducted by Los Alamos scientists: For if each nuclear test advanced the potential of the bomb as a military machine, it also increased the global burden of radioactive elements in the biosphere, overturning the "national security" logics supporting the nuclear arsenal by introducing the possibility of cellular mutations in plants, animals, and people on a planetary scale.

As the first U.S. popular culture text to depict the bomb not as a military weapon but as an ecological threat, *Them!* is worth revisiting in post–Cold War America. The film is important not only because it reveals a moment when the U.S. nuclear arsenal was not yet a normalized (all but invisible) aspect of everyday life but also because it is the urtext for an ongoing fascination with mutation in American popular culture, an important cultural legacy of the Manhattan Project.[2] Although it might appear today as a form of atomic kitsch, the film (an academy award winner for its one special effect: the giant ants) is played straight, and remains a compelling textual effort to assess the "newness" of the atomic age. The narrative begins, quite hauntingly, as a crime story: The police encounter a young girl, wandering the New Mexican desert alone in her bathrobe, too traumatized to speak (the image of a postnuclear survivor). Discovering a series of bizarre and violent murders in the area, including the girl's parents, the police struggle to make sense of crime-scene evidence (buildings destroyed from the inside out, recurring traces of sugar and formic acid, and an apparent lack of motive). The police soon call in the FBI, but these domestic agents of the security state are equally limited in their ability to assess the "crime" and make the imaginative leap required to see mutant nature as the cause. Frustrated by a lack of fingerprints, for example, the police and FBI agents stare without recognition at a strange impression found in the earth. The plaster cast of the impression reveals the footprint of a giant ant, constituting a criminal signature literally too large for the police to comprehend. Nuclear nature simply baffles; as one police officer put it, "lots of evidence, loaded with clues, but nothing adds up." The problem here is that the crimes are "unnatural" by the standards of prenuclear America, making the first problem of the nuclear age one of linking perception and imagination in a world operating by new laws of possibility. The remainder of the film traces the combined efforts of scientists, military personnel, and the FBI to contain the giant ants before they can reproduce (introducing a new kind of nuclear proliferation).

Them! both deploys and ridicules the military logics of containment by asking: If the giant ants are a crime, then who is responsible? The film enacts a split vision, both demonizing the ants as an external Other while recognizing that they are a creation of the U.S. security state. The terrible joke embedded in the title of the film suggests that the agents of destruction are foreign born rather than domestic—"theirs" rather than "ours." *Them!* ultimately argues that the dispersal of nuclear materials in the environment (recognized as a global phenomenon by 1954) is the source of a new kind of nature—mutant, wild, and *un*containable by the state. The U.S. nuclear complex may enable new technologies of mass death, but it also promotes new kinds of mutant life, as species are reinvented at the genetic level. As nuclear allegory and ecological critique, *Them!* also implicitly argues that human beings are not only responsible for creating a mutant ecology via the bomb, they are also part of this ecology, producing a future that is as unpredictable at the level of genetic stability as it is at the level of international relations.

Consider, for example, the concept of "background radiation," which references the baseline level of radiation considered inherent in the environment by federal authorities. The background radiation figure is the amount of radiation the average American receives in a given year from all sources; it is also the standard with which U.S. industrial radiation exposure rates are measured. The current background radiation rate for U.S. citizens is 360 millirems per year. Of this, 300 millirems come from "naturally" occurring sources, such as cosmic rays, radon, radiation from the surface of the earth, and from potassium-40 in our bodies. The remaining 60 millirems come from the cumulative atmospheric effects of industry—including nuclear medicine, nuclear power, and nuclear weapons testing (Wolfson 1991:60–63). What now constitutes the "background" field for all studies of radiation effects is a mix of naturally occurring and industrial effects. More specifically, the trace elements of Los Alamos weapons science now saturate the biosphere creating an atomic signature found in people, plants, animals, soils, and waterways. The Manhattan Project not only unlocked the power of the atom, creating new industries and military machines, it also inaugurated a subtle but total transformation of the biosphere. But if nature entered a new kind of nuclear regime in 1945, then how should we now assess that transformation? After all, the very idea of a background radiation standard is to establish a norm, a new definition of the "natural" in which the past effects of the nuclear complex are embedded as a fundamental aspect of the ecosystem. To appreciate the full scope of this nuclear revolution, we need to examine the effects of the bomb not only at the level of the nation-state but also at the level of the local ecosystem, the organism, and ultimately, the cell.

The background radiation rate constitutes an average and thus does not apply to any specific individual.[3] The true evaluation of nuclear risk is tied to specific exposures, rather than the background radiation count (which, although measurable, constitutes a negligible health risk). Arjun Makhijani and Stephen Schwartz, for example, identify seven classes of people negotiating health risks from U.S. nuclear production:

> (1) Workers in uranium mines and mills and in nuclear weapons design, production and testing facilities; (2) armed-forces personnel who participated in atmospheric weapons testing; (3) people living near nuclear weapons sites; (4) human experiment subjects; (5) armed forces personnel and other workers who were exposed during the deployment, transportation and other handling and maintenance of weapons within the Department of Defense; (6) residents of Hiroshima and Nagasaki in August 1945; and (7) the world inhabitants for centuries to come. [1998:396]

The enormous difference in the types and degrees of exposure among these populations demonstrates both the generality and specificity of the nuclear age: exposures are simultaneously collective (involving everyone on the planet) and highly individualized (involving specific classes of people—soldiers, miners, and nuclear workers). Although we all have trace elements from the Cold War nuclear project in our bodies, no two exposure rates are identical, as geographical location, occupation, and nuclear events (whether from nuclear industry, atmospheric nuclear tests, or accidents such as Chernobyl) combine with individual physiology and specific ecosystems to define actual rates and degrees of risk. Nevertheless, if we were able to track back in time and space, following the trajectory of the various chemicals and nuclear materials now in each of our bodies, one subset of these industrial signatures would lead back to Los Alamos and the Cold War national security project, offering a different vantage point from which to assess the nuclear age. From this perspective, America's nuclear project has witnessed the transformation of human "nature" at the level of both biology and culture, leading to the formation of new kinds of risk societies, unified not by national affiliation, but by exposure levels, health effects, and nuclear fear.[4]

These ever-present signatures of the nuclear security state constitute, for the vast majority of people, a theoretical, rather than a known, health risk. However, although studies of the survivors of Hiroshima, Nagasaki, the Marshall Islands, and Chernobyl, as well as of nuclear workers, have produced a detailed scientific understanding of the effects of high levels of radiation exposure, the effects of low-level radiation remain a subject of intense scientific debate.[5] It exists, as Adriana Petryna (2002) has put it, at the level of "partial knowledge," making the challenge of the nuclear age as much the regulation of uncertainty as the documentation of biological effects. This uncertainty is intensified by the specific attributes of radiation-induced illness, which includes a displacement in time (sometimes occurring decades after exposure) and a potential to be genetically transferred across generations. Recognizing the subtle but totalizing scope of the nuclear transformation of nature—the dispersion of plutonium, strontium, cesium, and other elements into the biosphere—challenges the traditional concept of a "nuclear test," which in Los Alamos has referred most prominently to the detonation of a nuclear device: For how does one define or limit the scope of the nuclear laboratory when its trace elements can be found literally everywhere on the planet? Thus, while Los Alamos scientists worked through the Cold War to perfect nuclear weapons as the core technology in a "closed world" system of military command, control, and surveillance (see Edwards 1996), their testing regime also transformed the biosphere itself, turning the earth into a vast laboratory of nuclear effects that maintain an unpredictable claim on a deep future.[6]

A concept of hybridity for scholars as diverse as Bruno Latour (1996), Donna Haraway (1997), and Paul Rabinow (1999) has been highly productive in revealing technoscientific objects to be complex fusions of nature and culture.[7] In thinking about radioactive natures, however, the discourse of hybridity—with its focus on parental elements and temporal orientation toward the present—limits our ability to recognize multigenerational reproduction across technoscientific forms and effects. As Robert Young (1995) reminds us, the original definition of the biological hybrid is tied to a concept of species. In sum, a species is that which can reproduce, whereas the hybrid is the infertile offspring of two different species or subspecies. Thus, the hybrid is in a strict sense a form of generational stasis, allowing one to separate analytically the distinct genetic lines that came together to create the infertile being. The world produced by the bomb, however, is structured by its totalizing scale (the entire planet) and by more localized, multigenerational effects that are highly changeable, rooted in any given moment as much in ambiguity or latency as in material fact. The 24,000-year half-life of plutonium, for example, presents a multimillennial colonization of the future, requiring a different temporal analytic for investigating radioactive ecologies.

To this end, I propose extending our theorization of the complexity of nature–culture forms via the concept of mutation. A mutation occurs when the ionization of an atom changes the genetic coding of a cell, producing a new reproductive outcome. As cells replicate over time, mutagenic effects can have three possible outcomes: (1) evolution, or an enhancing of the organism through a new adaptation to the environment; (2) injury, such as cancer or deformity; or (3) genetic noise, that is, changes that neither improve nor injure the organism but can still affect future generations. A concept of mutation implies, then, a complex coding of time (both past and future); it assumes change, but it does not from the outset judge either the temporal scale or the type of change that will take place. It also marks a transformation that is reproduced generationally, making the mutation a specific kind of break with the past that reinvents the future. Engaging the U.S. nuclear project through the lens of mutation, rather than hybridity, privileges not only the institutional and technoscientific networks needed to construct the bomb but also the wide-ranging and long-term social and environmental effects of the production complex itself. The ecological effects of atmospheric nuclear testing, for example, may not be fully realized for decades, and an understanding of their cultural effects requires an investigation into the different conceptions of nature that inform local communities. Post–Cold War studies at the Semipalatinsk nuclear test site in Russia, for example, have demonstrated elevated mutation rates in the children of populations exposed to fallout during the 1950s (see Dubrova et al. 2002, and also 1996). Similarly, Adriana Petryna (2002) has shown in her remarkable study of Chernobyl how exposed populations now pursue a "biological citizenship" in which everyday life is centered on the negotiation of risk, health care access, and the psychosocial effects of radiation-induced trauma (see also, Lifton 1991). Nuclear science has transformed human culture at the cellular level in each of these cases, producing new kinds of ecologies, peoples, and social orders.

Although the Cold War American nuclear project has not yet produced giant ants, it has distributed new material and ideological elements into the biological bodies of citizens and the social body of the nation that continue to proliferate, promising unpredictable outcomes. As such, the Manhattan Project remains an unending experiment: Nuclear war is still possible today, just as the biosphere and specific social orders continue to be transformed by the effects of (post)–Cold War military nuclear science. While each U.S. citizen negotiates the traces of Los Alamos science in their bodies and biosphere—making each of us real or potential mutants—the nuclear future remains highly mobile. Consequently, the remainder of this article investigates debates and practices involving new "species" logics in the nuclear age, examining how the pursuit of security through military techno-science has raised questions about the structural integrity of plants, animals, and people. As we shall see, the nuclear saturates both environments and social imaginations in New Mexico, revealing mutant ecologies subject to new possibilities. The ethnographic challenge, I suggest, is to realize a deep sense of this mutating future and assess how life is currently structured within specific locales.

Nuclear Test Subjects

> Any person living in the contiguous United States since 1951 has been exposed to radioactive fallout, and all organs and tissues of the body have received some radiation exposure.
>
> —U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, and the National Cancer Institute

> Radiation can make cells lose their memory, and loss of memory seems to be one of the cultural effects of the bombs too, for Americans forgot that bomb after bomb was being exploded here.
>
> —Rebecca Solnit, *Savage Dreams*

As a state project, the Cold War nuclear arsenal seems to have distributed risk to human populations on a species scale. As the Department of Health and Human Services, the Centers for Disease Control and Preventions, and the National Cancer Institute underscore in a 2001 joint report, all Americans maintain traces of U.S. nuclear testing in their bodies—"all organs and tissues" have been exposed. However, as Rebecca Solnit (1994) reminds us, this national exposure also became an exercise in national amnesia over the long course of the Cold War, as U.S. citizens seemed to forget or repress the implications of living within a national nuclear complex. Much of this can be traced to the cultural repercussions of the move to underground nuclear testing in 1963, which was both a public health initiative and a means of making nuclear testing more covert in a world of competing states. Without the visible effects of the mushroom cloud to remind citizens of the ongoing American nuclear project, the discourse of mutation became a generalized concern in American culture, rather than an explicit critique of the nuclear security state. The post–Cold War period, however, has witnessed a renewed awareness of the ecological effects of the nuclear complex as a result of new environmental laws, the declassification of information about Cold War nuclear projects, and the mounting human and environmental cost of nuclear production itself.[8] The new visibility of America's Cold War nuclear project, however, does not take the shape of a mushroom cloud but is, instead, measured in terms of toxicity levels, cancer rates for certain populations, and in the ecological challenges of Cold War nuclear production sites. For example, the report by the U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, and the National Cancer Institute (2001:6–7) estimates that aboveground nuclear testing in the continental United States (1951–61) has produced 11,000 cancer deaths and somewhere between 11,300 and 212,000 thyroid cancers among U.S. citizens. As participants in this radioactive ecology, how should we—as citizens, residents, and biological beings—now evaluate the dialectics of survival and sacrifice that remain at the center of the nuclear state? What has changed about this dialectic since the demise of the Soviet Union and the orchestration of a post–Cold War American nuclear complex?

Let us start with two specific illustrations of radioactive nature taken from opposite ends of the Cold War: the first involves a fish; the second, a bull—one an image of radioactive death, the other an image of radioactive life. In 1946, Operation Crossroads was designed to sink the remnants of the Japanese navy and to display American nuclear power for a global audience (see Figure 1). For scientists, it was also an opportunity to study the biological effects of America's fourth and fifth nuclear explosions (after Trinity, Hiroshima, and Nagasaki) on a wide variety of test animals as well as on the environment of the Marshall Islands. In his memoir of radiation science on Operation Crossroads (ominously entitled *No Place to Hide*), David Bradley assesses the ecological effects of the bomb and offers a startling new register of the nuclear age—the "radio-autograph":

> Radio-autographs are made by taking a small fish, slicing it longitudinally down the middle, drying it in a blast of warm air, and then placing the fish, cut side down, on a photographic plate. After a suitable time the radioactivity present in the tissues of the fish will have exposed the adjacent film, which, when developed, will then outline the fish in tones which are proportional to the radioactivity present. . . . Almost all seagoing fish recently caught around the atoll of Bikini have been radioactive. Thus the disease is passed on from species to species like an epizootic. The only factors which tend to limit the disease, as distinguished from infectious diseases are the half-lives of the material involved, and the degree of dilution and dissemination of the fission products. [1948:125–126]

Almost all seagoing fish have been radioactive. The radio-autograph constitutes a new sign of modernity, one made visible simply by placing the biological being on photographic film. The unnatural energy signature of the creature then

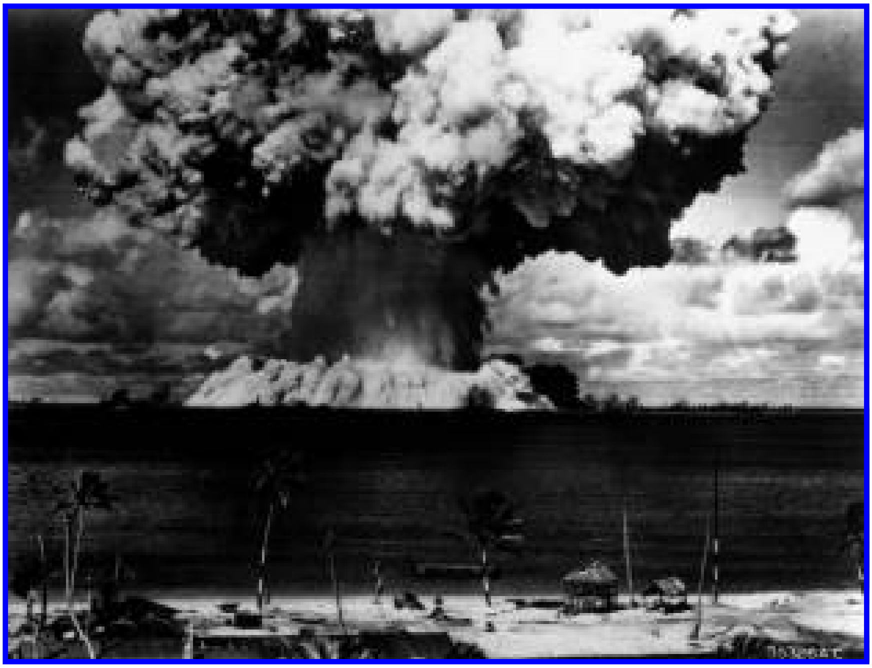

Figure 1
Operation Crossroads, Test Baker. (Photo courtesy of U.S. National Archives.)

produces its own negative image, drawn in the mirrored form of contaminated organs and orifices. Bradley approaches radiation exposure as a disease and is concerned with how it moves through the food chain; he sees no technological possibility of containing exposure rates other than the one intrinsically provided by the half-life of the involved nuclear materials. Although Bradley's radio-autographs document radiation exposure rates at a specific moment in time, they are also dialectically related to the future, as the Bikini Island ecosystem continues to negotiate the eight-day half-life of iodine-131, the 28.5-year half-life of strontium-90, and the 24,500-year half-life of plutonium. Radiation exposure is presented here as a form of incipient death, moving through the biosphere as contamination or infectious disease. The human populations affected by Operation Crossroads, including Marshall Islanders and U.S. military personnel, are still negotiating their entry into this radioactive ecology (Weisgall 1980, 1994). Concerned now with what their own radio-autographs might document, they constitute (along with Manhattan Project personnel and the survivors of Hiroshima and Nagasaki) the first distinct classes of a new global nuclear "risk society" (Beck 1992).

If the pre–Cold War radio-autographs of irradiated fish from Operation Crossroads offer us an image of a nuclear ecology of damaged organs, a corrupted food chain, and death, another image of radioactive nature in the post–Cold War period privileges survival. The Chernobyl site, which is, for many people, now the primary reference for radiation exposure, provides perhaps the clearest illustration of this new possibility. After the meltdown and fire in one of the four nuclear reactors in 1986, a 30-kilometer "zone of exclusion" was created around the Chernobyl facility, which was also encased in a concrete shell known as the "sarcophagus." By the late 1990s, 3.5 million Ukrainians had obtained legal recognition as "sufferers" of what the Soviet State had first referred to as a "controlled biomedical crisis" (Petryna 2002:4–5). During the 1990s, a bull was found grazing in the contaminated grasses within the zone of exclusion. The apparent health of the animal became a source of commentary and pleasure for workers and neighboring communities who were dealing with the daily effects of radiation exposures and uncertainty in their lives. However, radioecologists named the bull Uran (after uranium) because of the amount of radionuclides in its system, and they began breeding the bull to study the genetic effects of radiation exposure (Fusco and Caris 2001; Petryna 2002; Stephens 2002; Theroux 2001). Unlike the radioactive fish from Operation Crossroads, the cattle from the exclusion zone sired by Uran were immediately valued not as signs of damaged nature but as "survivals," illustrations of a natural adaptation to a radioactive environment.

To be sure, the four decades separating the Crossroads and Chernobyl events involve a complicated history of nuclear imagery, science, and Cold War public policy. Yet these cases are linked, as they demonstrate the progression of a new kind of "species" knowledge: If the Cold War logics of deterrence sought to preserve the stability of the present through nuclear weapons, the power of the radioactive, yet thriving, bull is that it is neither pure nor hybrid but alive and potentially mutant. Life within a radioactive zone changes the terms by which we can evaluate the nuclear revolution; it cannot be narrated within a discourse of purity—of either the nation-state or the state of nature. The question increasingly asked today concerns the quality of biosocial transformations set in motion by nuclear science. The nuclear age, from this perspective, still involves a dialectic of survival and sacrifice, but this process has expanded to include an ecological dynamic that is both external to, and preceding, the possibility of nuclear war. Recognizing radioactive natures redefines the question of nuclear security, linking the survival of the nuclear-powered state to the integrity of both social and cellular reproduction over time.

Los Alamos scientists recognized the biological effects of radiation from the start of the Manhattan Project, making Operation Crossroads an early step in an ongoing biological as well as military experiment. The goal of this research was not to stop the exposure rates, however, but to figure out how to mitigate the ecological effects of the bomb during an escalating Cold War arms race. In fact, there was no separation between the experiment and its real world effects during the aboveground-testing regime of 1945–63. Operation Plumbbob, a series of 30 nuclear detonations conducted at the Nevada Proving Grounds in 1957, for example, was designed to advance nuclear weapons science as well as study the effects of a nuclear explosion on a variety of military machines (planes, helicopters, blimps, and tanks), shelters (military bunkers, foxholes, and ammunition depots), and weapons (land mines and missile guidance systems). A significant part of the test series was also devoted to investigating the environmental and biological

Figure 2
Radiation tests on pigs in metal containers, Operation Plumbbob (from DOD film, *Operation Plumbbob: Military Effects Studies*).

effects of nuclear radiation (U.S. Defense Nuclear Agency 1981a). The Department of Defense (DOD) produced a 31-minute film of the test series entitled "Operation Plumbbob: Military Effects Studies," which was declassified in 1997. Under the subheading of "Biomedical Testing," the narrator states that a "major portion of the experiment was devoted to testing the effects of nuclear weapons on a large biological specimen: the pig."

Prior to Shot Wilson, 135 pigs were placed in individual aluminum containers and distributed in a large grid formation on the test site (see Figure 2).[9] The bomb exploded with a greater-than-expected force (10 kilotons), exposing the pigs to high levels of gamma radiation: Only two of the 135 pigs lived more than 30 days, making the experiment, by its own terms, a failure. Shot Priscilla, a Los Alamos project to study how to reduce atmospheric fallout, was also designed to study "radiation, thermal, and mechanical injury effects" on living beings (U.S. Department of Defense 1957). Seventy-eight pigs were shaved (to simulate human skin), painted with various materials or covered in fabric, placed in elevated boxes, and then exposed to the nuclear blast (see Figure 3). The pigs were used to research protective fabrics for military uniforms, as well as various flash-burn creams and different types of thermal shielding (U.S. Defense Nuclear Agency 1981c:52–53). Moreover, 710 pigs were distributed in open pens and in small open-faced boxes placed various distances behind sheets of glass. The experiment exposed one group of pigs to radiation effects while creating shrapnel injuries in others, of the kind soldiers might experience in a nuclear strike. The irradiated and wounded pigs were then used to field-test surgical techniques. As with Shot Wilson, Shot

Figure 3
Radiation and blast effects test on pigs (from DOD film, *Operation Plumbbob: Military Effects Studies*).

Priscilla was a failure in the biomedical arena because of the nearly 100-percent fatality rate caused by "mechanical injury to the organism" and "massive radiation" exposure.

The DOD film presents a slow-motion image of the blast wave hitting a pen filled with the animals and then documents the efforts of scientists to collect the injured and dead bodies after the test. In describing the experiment, the DOD narration identifies the pig as "an instrument" for radiation research, and in one close-up, the film shows a chart outlining the body of a pig—used by radiation scientists to mark the injury and radiation effects on each of the animals. The rationality of this preprinted form (see Figure 4), which suggests an industrial logic of production and control, is at odds with the chaos documented in the postexplosion scenes of technicians in white anticontamination suits and ventilators trying to round up the visibly wounded and dying animals. The effects of the nuclear blast on the instrument-body of the pig is portrayed in the film with the same efficiency as those demonstrated on various kinds of machinery. In Operation Plumbbob, the nuclear age involves not only military technoscience (the Los Alamos–designed nuclear device) and military capability (tanks and planes) but also the fragility of the biological being to blast, thermal, and radiation effects. Concluding that the nearly 100-percent death rate among the 845 pigs can also "be applied to man," the biomedical project of Operation Plumbbob seems successful only in constructing the traumatized organism as an institutional project. Nuclear trauma is not avoided here—indeed, it is instrumentally and methodically pursued—in an effort to test the fragility of human and animal bodies to nuclear radiation and blast effects.

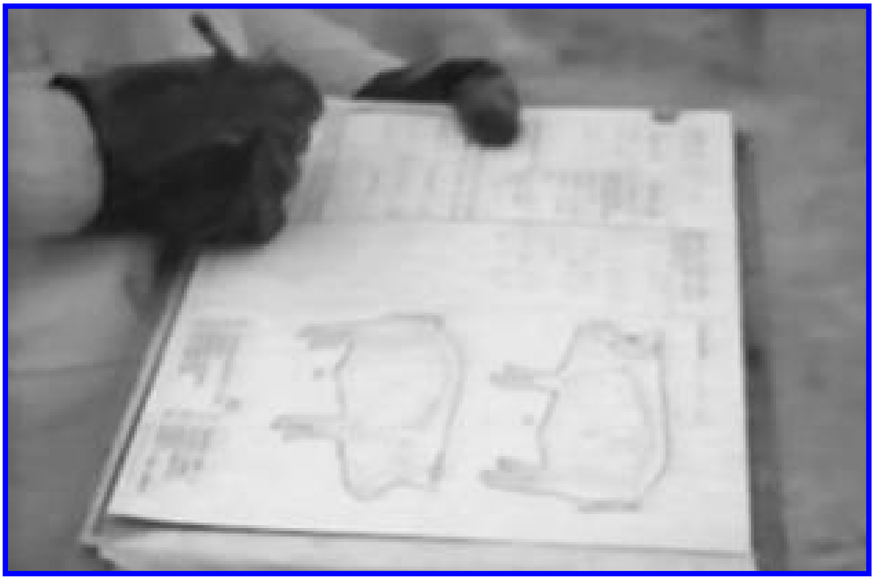

Figure 4
Chart of pig (from DOD film, *Operation Plumbbob: Military Effects Studies*).

Each aboveground nuclear test was a biomedical experiment that explicitly sought to mitigate the effects of the bomb by methodically applying its force to plants, animals, and ultimately, people. Pigs, dogs, sheep, cows, monkeys, and mice were used to test the effects of radiation on different species, utilizing skin, lungs, eyes, blood, and genetic material as a test of how radiation exposure traumatizes a biological being in the millisecond of an atomic blast and over longer periods of time as the mutagenic effects of radiation exposure occur. The protected body of the Cold Warrior, increasingly rendered as cyborg in the cockpit of planes and other military machines, was thus prefigured by the vaporized, mutilated, and traumatized animal body. The instrumentalization of the pig in Operation Plumbbob is not only a marker of the enormous stakes of the Cold War nuclear arms race, but it is also an important illustration of a larger production and deployment of radioactive natures since 1945. In a variety of ways, soldiers and citizens were also part of this experimental regime, exponentially expanding the frame of the nuclear experiment from the confines of the Nevada Test Site to the global biosphere: As the U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, and the National Cancer Institute document reminds us, "all organs and tissues of the body have received some radiation exposure" (2001:2).[10] If, however, the Cold War nuclear project began with a pursuit of the traumatized body, then what has happened to these nuclear natures in the subsequent decades? As we shall see, the radioactive body once studied for its injury is now celebrated as a Cold War survival and embedded within a new discourse of ecological purity.

Radioactive Natures: Life in the Wildlife/Sacrifice Zone

At the end of the Cold War, the U.S. nuclear complex formally occupied a total continental landmass of over 3,300 square miles, involving 13 major institutions and dozens of smaller production facilities and laboratories (O'Neill 1998:35). These production sites were predominantly located in isolated, rural areas as a complex form of domestic development. Huge new industrial economies were created in Oak Ridge (Tennessee), Hanford (Washington), and Los Alamos (New Mexico) in 1943; and later in Aiken (South Carolina), Amarillo (Texas), Idaho Falls (Idaho), Rocky Flats (Colorado), and at what became the Nevada Test Site (see Hales 1997; O'Neill 1998). It was in these mostly rural, nonindustrial locations that nuclear materials were mass produced, nuclear weapons were built and tested, and nuclear waste was stored, fusing local ecologies and local communities with the American nuclear project. The internal logics of nuclear development required deliberate acts of territorial devastation, producing an archipelago of contaminated sites stretching across the continental United States from South Carolina to Nevada, from Kentucky to Washington, and from Alaska to the Marshall Islands. This "geography of sacrifice," as Valerie Kuletz (1998) has called it, is currently estimated to entail a \$216–\$400 billion environmental restoration project for those sites that have been identified as "remediable," and it is likely to cost more than the Cold War nuclear arsenal itself (see Schwartz 1998; U.S. Department of Energy [DOE] 1995a, 1995b). Nuclear security has required complex new forms of internal cannibalism, as both the biology of citizens and the territories of the state encounter an array of new nuclear signatures after 1943.

In the post–Cold War period, the U.S. nuclear complex has implicitly recognized these transformations through a new type of territorial reinscription. On October 30, 1999, for example, Secretary of Energy Bill Richardson announced the formation of a 1,000-acre wildlife preserve within a 43-square mile territory of Los Alamos National Laboratory (LANL). The new White Rock Canyon Preserve was singled out by the Department of Energy (DOE) as a "unique ecosystem" that is "home to bald eagles, peregrine falcons, southwestern flycatchers, 300 other species of mammals, birds, reptiles, and amphibians, as well as 900 species of plants" (U.S. Department of Energy, Los Alamos Area Office 1999:1). As Secretary Richardson explained:

> How fitting that we are here today at Los Alamos, the place that witnessed the dawn of the atomic age. . . . In places of rare environmental resources, we have a special responsibility to the states and communities that have supported and hosted America's long effort to win the Cold War—and we owe it to future generations to protect these precious places so that they can enjoy nature's plenty just as we do. Los Alamos's White Rock Canyon is such a place, an able bearer of New Mexico's legacy of enchantment. After today, it will be more so as we celebrate the reunification of land and community. [1999:1]

We celebrate the reunification of land and community. The "wildlife preserve," as a concept, forwards a claim on purity, marking specific ecologies worth preserving as precious resources in a "state of nature." What can such a claim mean, however, in the context of a U.S. nuclear site? Richardson's appeal to a "legacy of enchantment" as well as to the reunification of land and community in New Mexico comes after a decade of intense environmental politics concerning the Cold War legacies of nuclear weapons work at Los Alamos. The post–Cold War period began in New Mexico with the near simultaneous announcements of a moratorium on nuclear weapons tests and the designation of 2,200 contaminated sites within LANL, requiring an estimated cleanup of over $3.3 billion (U.S. Department of Energy 1995b:xiv). As many New Mexicans discovered the scale of Cold War nuclear research at Los Alamos through its environmental costs, community groups throughout northern New Mexico mobilized for health studies as well as increased surveillance of water, soil, and air quality. The reunification of land and people proposed by the "wildlife preserve" recognizes the unique cultural investments of Pueblo and Nuevomexicano communities in the area now occupied by Los Alamos (see Masco 1999; in press).[11] However, the discourse of "preservation" enabling such recognition can only do so by ignoring the long standing practices of environmental ruin, informing past and present research at the laboratory.

Rather than focusing on the radio-autographs of fish from Bikini Island or the instrumentalization of the pig in Nevada, the DOE now assumes responsibility for preserving the southwestern flycatcher and the peregrine falcon in northern New Mexico. In doing so, the DOE attempts to expand retroactively its Cold War mission from nuclear deterrence to environmental protection. This ideological project to link the "national security" offered by the atomic bomb during the Cold War to sustaining the biodiversity of U.S. territories, however, forwards a deep structural contradiction. The global effects of nuclear production have transformed the global environment, making the biosphere itself a postnuclear formation. Because the trace elements of atmospheric fallout are now ubiquitous in soils and waterways, flora and fauna, the "nature" of wildlife as a concept has changed in the nuclear age. If exposure is now a general condition—a question of degree rather than kind—then what does it mean to promote such images of survival in the midst of contamination?

This recuperation of "nature" within post–Cold War debates about the environmental and health dangers of nuclear production articulates a new form of state territoriality. In the continental United States alone, the DOE has recently transformed by legislative fiat over 175,800 acres of land from industrial nuclear sites to wildlife preserves. Carved out of the vast security buffer zones established around nuclear sites, most of these areas were fenced off in the middle of the 20th century and isolated from human contact during the Cold War. Consequently, these sites were among the most heavily fortified wilderness areas in the world. By presenting these sites as untouched in over 50 years, the DOE seeks to redefine the value and object of that military fortification, replacing nuclear weapons systems with biodiversity as the security object of the nuclear state. This suturing together of wildlife preserve and national sacrifice zone has become an expansive post–Cold War project.

At the Savannah River Site, which produced plutonium and tritium for the U.S. nuclear arsenal, 10,000 acres (of the 200,000-acre nuclear facility) became the Crackerneck Wildlife Management Area and Ecological Reserve in 1999 (U.S. Department of Energy, Savannah River Operation Office 1999). Celebrating some 650 species of aquatic life found on the site, the DOE presented a remarkable image of biodiversity to the public. DOE representatives failed to mention, however, that the unusually healthy alligators and rather large bass fish found at the Savannah River Site are also unusually radioactive (Associated Press 1999). Their bodies contain cesium-137, a byproduct of nuclear material production on the site, which is home to five nuclear reactors. The Savannah River Site now presents a uniquely modern contradiction: The site maintains a massive environmental problem in the form of 34 million gallons of high-level radioactive waste, a multimillennial challenge to the future, but it has been rescripted by the nuclear state as an ecological reserve preserved, as the DOE notes, for "future generations."

At the Idaho National Engineering and Environmental Laboratory (INEEL), 74,000 acres are now included in the Sagebrush Steppe Ecosystem Reserve. The DOE has devoted this preserve to the protection of some 4,000 species of plants and 270 species of animals—including the ferruginous hawk, the pygmy rabbit, and Townsend's big-eared bat (U.S. Department of Energy, Idaho National Engineering and Environmental Laboratory 1999). Inaugurating the reserve, Secretary Richardson remarked:

> The Department of Interior estimates that 98 percent of intact sagebrush steppe ecosystems have been destroyed or significantly altered since European settlement of this country. Because the INEEL has been a largely protected and secure facility for 50 years, it is still home to a large section of unimpacted sagebrush habitat. Our action today will help preserve for future generations one of the last vestiges of this important system. [1999:1]

INEEL—a largely protected and secure facility. With 52 nuclear reactors and 11 gigantic tanks filled with 580,000 gallons of high-level nuclear waste, INEEL is redefining the definition of "protected" and "secure"—as well as "impact" and "risk"—for distant future generations. Although Townsend's big-eared bat and the pygmy rabbit have gained new state recognition via the reserve, their new status is primarily a bureaucratic one and does not address the mobility of animals, ecosystems, and radionuclides between territories identified as wildlife reserves and nuclear production sites.

The hard insight informing these new wildlife preserves is that isolation from human traffic provides an enormous ecological benefit: Human contact is more immediately toxic for many ecosystems than are radioactive materials. This dual structure of land as both wildlife reserve *and* sacrifice zone seems to argue, however, that nuclear materials can be kept in place and that the border between preserve and wasteland can be effectively patrolled over millennia. This logic is trumped most convincingly at the Hanford Reservation in Washington State, which produced plutonium for the U.S. arsenal from 1945–92 and is now recognized as the most seriously polluted site in the United States. The DOE has recently devoted 89,000 acres of Hanford's 540 square miles to preserving the long-billed curlew, Hoover's desert parsley, and Columbia yellow cress (U.S. Department of Energy, Pacific Northwest National Laboratory 1999). However, mulberry trees on the Hanford Reservation have been showing increasing amounts of strontium-90 over the last decade (Lavelle 2000); and the Russian thistle plant has recently created a new kind of environmental hazard: the radioactive tumbleweed (Associated Press

2001; Stang 1998). The Russian thistle shoots its roots down 20 feet into the earth, sucking strontium-90 and cesium into its system from contaminated areas. The head of the plant eventually breaks off to become a windblown radiation source. Hanford now spends millions of dollars each year managing this form of contamination and has crews armed with pitchforks patrolling the reservation in trucks to wrangle the radioactive weeds. This inability to enforce the distinction between wilderness and wasteland was further dramatized at Hanford in 1998, when fruit flies landed in liquid radioactive material and carried contamination far and wide over the next weeks, requiring nothing less than a $2.5 million dollar DOE cleanup operation (Stang 1998).

Radioactive tumbleweeds, contaminated fruit flies, and toxic alligators—these are all survivals of the Cold War nuclear project as well as new forms of nuclear nature. Adjacent to each of the DOE wildlife preserves, however, are sites that are not just minimally radioactive according to federal standards but present such profound environmental hazards that they will need to be fenced off and monitored for, in some cases, literally tens of thousands of years. These sites represent Cold War survivals of another kind. Despite the rhetorical and institutional effort to find areas of "purity" within the ecology of the nuclear complex, the broader context involves a massive state-sponsored territorial sacrifice during the Cold War that has been wildly productive in specific areas. The U.S. nuclear complex could not have produced 70,000 nuclear weapons from 1943–92 without favoring industrial production over environmental concerns. Just as the current background radiation rate normalizes the atmospheric effects of aboveground nuclear testing as an aspect of nature, the new wildlife zones offer an image of a nature created through nuclear politics and radioactive practices. The wildlife preserve is thus an exception that proves the rule within the nuclear complex. Despite the new bureaucratic recognition of the ferruginous hawk, the pygmy rabbit, and the larkspur, the division between normal, abnormal, and pathological is being redefined in these nuclear sites, as contaminated nature is recognized to be not only valuable and robust but, to greater or lesser degrees, ever present. In other words, the experimental projects that produced and now maintain the bomb have collectively turned the entire biosphere into an experimental zone—one in which we all live—producing new mutations, as we shall now see, in both natural and social orders.

Environmental Sentinels, or the Militarization of the Honey Bee

Arturo Escobar has recently argued for a prismatic view of nature that "is concerned with finding new ways of weaving together the biophysical, the cultural, and the technoeconomic for the production of other types of social nature" (1999:2). He suggests a tripartite model focusing on the interaction between distinct regimes of nature: "organic nature" (an ecological view of the linkages between human and natural forms), "capitalist nature" (involving the objectification, management, and resource extraction of nature), and "technonature" (including biocultural technologies that reinvent society and nature such as the new genetics).[12] Within this scheme, understandings of nature are always positional and hybrid, requiring an ethnographic framing of physical context, cultural logic, and global–local forms.

The value of Escobar's approach is precisely its openness to new configurations of nature and society and its attention to local detail; his political ecology is one that is in motion, subject to continuing historical transformation but still capable of recognizing multiplicity. Pursuing this kind of a political ecology through a theory of mutation focuses critical attention on the multigenerational outcomes of specific fusions of nature and culture, of environment and technology, of the global and the local. Mutation is a logic of generational reproduction that both privileges the multiplicity that is at the center of Escobar's useful formulation of a political ecology and acknowledges environmental effects, but it is also one that requires a critical stance toward each instantiation of the mutant form—as evolution, as degeneration, or as noise.

In the previous section, we saw how the Cold War U.S. nuclear project produced new forms of radioactive nature, now paradoxically marked for federal conservation as valued "survivals" of industrial nuclear America. Only possible because of the massive state-sponsored ecological sacrifices of the Cold War nuclear complex, these newly recognized zones of biodiversity are not untouched by the nuclear state. Indeed, many sites contain radioactive signatures that could change the biological structure of plants and animals over time, making the deep future of the radioactive wildlife preserve (as a natural and socially valued space) an open question. The radioactive future of the Cold War nuclear complex is already mutating in the post–Cold War period, producing a complex mobilization of future generations, technoscience, and state institutions. The DOE has not only offered up zones of conservation to future generations but also acknowledged that as many as 109 sites within the nuclear complex are too contaminated to remediate effectively. The challenge of what to do with these radioactive sites over decades, centuries, and in some cases, millennia, is now articulated through a new discourse of environmental surveillance and control known as "long-term stewardship." On its homepage, the DOE defines this project in the following manner:

> The Long-Term Stewardship Program will maintain and continuously improve protection of public health, safety, and the environment at a site or portion of a site assigned to DOE for such purposes. This mission includes providing sustained human and environmental well-being through the mitigation of residual risks and the conservation of the site's natural, ecological, and cultural resources. Mission activities will include vigilantly maintaining "post-cleanup" controls on residual hazards; sustaining and maintaining engineered controls, infrastructure, and institutional controls; seeking to avoid or minimize the creation of additional "post-cleanup" long-term stewardship liabilities during current and future site operations; enabling the best land use and resource conservation within the constraints of current and future contamination; and periodic re-evaluation of priorities and strategies in response to changes in knowledge, science, technology, site conditions, or regional setting. The Long-Term Stewardship Program will coordinate activities to identify and promote additional research and development efforts needed to ensure this protection and to incorporate new science and technology developments that result in increased protection of human health and the environment and lower costs.[13]

Sustained human and environmental well-being through the mitigation of risk. The Long-Term Stewardship Program approaches the radioactive and chemical legacies of Cold War nuclear production as a bureaucratic, as well as technoscientific, problem. Promising an increasingly intimate interaction with contaminated sites, the Long-Term Stewardship Program hopes to minimize future environmental effects by systematically deploying as yet undeveloped technologies (see also, U.S. Department of Energy 1999, 2001). Through constant surveillance, the Long-Term Stewardship Program naturalizes the environmental problems of the Cold War by orchestrating institutions, technoscientific projects, and communities around managing contaminated ecologies and industrial sites for an indefinite future. This is a utopian program that imagines perfect management of Cold War nuclear waste and contaminated sites for millennia—despite the prior 50 years of environmental neglect.

Creating "sustained human and environmental well-being" in a postnuclear environment, however, requires a complex new form of governmentality. For Foucault (1991), governmentality is the focus of the state on policing its population to improve the health and well-being of its citizens. In long-term stewardship, the logic of national security is inverted; the threat of foreign arsenals and armies are replaced by an internal discourse of contamination and territorial colonization.[14] In this context, governance means protecting citizens from the industrial effects of the nuclear security state, thus redrawing the lines between policing and welfare. However, it is not clear how "environmental well-being" can or will be defined. The DOE cannot return ecosystems to a preindustrial, prenuclear state. Rather, "clean-up" here means meeting U.S. regulatory standards, which are dependent on expected land use.[15] The hope of the Long-Term Stewardship Program is that, through surveillance and applying cutting-edge science to the environmental legacy of the Cold War, a kind of ecological stasis can be achieved in the near term, as science improves over time to solve the problems eventually posed by radioactive contamination and waste. However, in recognizing that some sites are too damaged to treat effectively, the program also reveals that the Cold War still has a powerful claim on a deep future. With budget projections currently made out only to the year 2070, the DOE estimates that the program will require $100 million per year simply to maintain the 109 long-term stewardship sites (U.S. Department of Energy 2001:108).

If the wildlife zone is one new form of nuclear nature, the long-term stewardship site is another, with an equally deep claim on future generations. Indeed, in orienting scientists, technologies, and communities around long-term stewardship sites, the DOE is also creating long-term stewardship communities, producing entirely new ecosocial orders. To make this point, we do not have to look thousands or even hundreds of years into the future. One long-term stewardship site at LANL, known as Area G, has been the laboratory's primary nuclear waste site since 1957. Area G is a 100-acre facility located on Mesita del Buey, one of the finger-like mesas that make up the Pajarito Plateau. Low-level radioactive waste (consisting mostly of objects contaminated during laboratory operations), as well as significant quantities of plutonium-239 and uranium-238 from nuclear weapons research, is stored in large pits and deep shafts. Although inventories have been carefully documented since 1988, few records were kept for the period 1957–71, and poor records for the period 1971–88. This incomplete knowledge of what is in Area G is important because just to the east of the site is the town of White

Rock (population 6,800) and immediately north is San Ildefonso Pueblo territory. Pueblo members collect plants and hunt game in the shadow of Area G, as well as maintain shrines and sacred sites in the area. A recent laboratory "performance assessment" concludes that Area G will be completely full by 2044, initiating a new kind of territorial project:

> Active institutional control will continue for a period of 100 years (between 2047 and 2146). During institutional control, site access will be controlled, environmental monitoring will be performed, and closure cap integrity will be maintained. After the institutional-control period, it is assumed the site will be maintained by the DOE or its equivalent for as-yet undefined industrial uses. This industrial-use period is assumed to prevail for the 900 years remaining in the compliance period (between 2147 and 3046). [Hollis 1997:10]

The 900 years remaining in the compliance period (between 2147 and 3046). Evaluating the exposure risks to future populations along a variety of intrusion scenarios, the report confirms that the Manhattan Project inaugurated a new ecological regime on the Pajarito Plateau—which is now intimately involved with negotiating the 24,000-year half-life of plutonium and other nuclear materials (see Rothman 1992 and Graf 1994). Currently evaluating risk only on a 1,000-year time frame, Area G is nonetheless one instantiation of a larger Cold War nuclear legacy that the discourse of long-term stewardship rhetorically seeks to contain using rational technoscientific measures.

The Area G Performance Assessment concludes, "The ability to contain radioactivity locally depends largely on nature, while the ability to prevent intrusion depends solely on man." It therefore assumes from the start that "current natural conditions will prevail" and "a government entity will maintain the site and control access to it" for the next 1,000 years (Hollis 1997:16). Both nature and the state are, for the sake of the study, assumed to be stable entities across the next millennium, even as the evidence of the last 50 years shows a dramatic change in both. Indeed, more subtle changes are already shaping the nuclear future of the Pajarito Plateau, offering a new state of nature, more mutant than stable. Plumes of tritium contamination as well as chemical residues from high explosives are already leaking from Area G, demonstrating that the geology of the Pajarito Plateau is more permeable than previously assumed.[16] Traces of tritium found in wells drilled around LANL have also raised concerns about the mechanisms of transport through the geological tuft and the long-range safety of the regional aquifer.[17] Even as the performance assessment assumes a forever-vigilant state agency to watch over a stable ecosystem at Area G, environmental surveillance is revealing a more mobile ecological formation. Indeed, surveillance itself has become the basis for new kinds of nature.

Consider the role now played by the Italian honeybee *(Apis mellifera)* at Area G. As a creature that flies over a wide area foraging for pollen and nectar in flowers and then returns to a fixed location (the hive) to produce honey, the honeybee is a natural environmental surveyor. Los Alamos scientists have demonstrated that the honeybee is particularly sensitive to tritium, a radioactive substance used in nuclear weapons to enhance the size of the explosion and notoriously difficult to contain.

Deploying the honeybee as an environmental tool since the late 1970s, scientists have documented increasing tritium contamination rates at Area G through the 1990s (Fresquez et al. 1997). This instrumentalization of the honeybee takes more than one form at Los Alamos, but, in the context of Area G, it reveals a profound transformation in ecological regimes. Neighboring Pueblo communities identify mesa tops as areas of particular cultural importance, containing shrines and sacred sites that participate in a different conception of nature. Pueblo cosmology has traditionally worked, not to deploy nature as a technoscientific object, but to integrate Pueblo members into the local ecology (see Ortiz 1969). Within Eastern Pueblo cosmologies, the bee plays a crucial role in pollinating plants and is both a symbol and an agent for life itself; consequently, pollen figures prominently in ceremonies of purification and seasonal renewal. The Manhattan Project replaces this ecological regime with one that focuses on the technoscientific deployment of nature (first, by transforming nuclear energy into a bomb and then by mobilizing the bee as an environmental monitor). The value of the bee, in this new context, is no longer as a life-giving entity but as a toxic being, marking the transformation of the plateau from a wild space of nature to a new kind of mutant ecology.

Within this ecology, the bee becomes an agent of the national security state. The militarization of the bee is an expansive project, linking "environmental surveillance" at Los Alamos with a broader DOD concern with "controlled biological systems" research. As the Defense Advanced Research Projects Agency (DARPA) describes this project on its homepage:

> The principal objective of the program is to utilize biological organisms for real-time collection of information in the environment. Applications of interest include controlling the distribution of biological systems for real-time monitoring of individual or populations of organisms (e.g., swarms, hives, dens, schools) to seek out and collect information in the environment (air, land, or water) about agents of harm including chemical or biological weapons and unexploded ordnance. . . . To accomplish this objective, the program will seek to monitor and utilize the sensory signals (e.g., chemical, visual, thermal, acoustic, other) and sensorimotor behavior employed by biological organisms to forage and reproduce in their environment.[18]

To utilize biological organisms for real-time collection of information. DOD research on controlled biological systems currently takes the form of three novel deployments of nature: (1) vivisystems, the use of insects (bees and moths) and other animals as "environmental sentinels" (currently used for tracking chemical weapons, explosives, and radioactive materials in the environment); (2) hybrid biosystems, an effort to create cyborg bugs and animals for surveillance or, as the project puts it, to "integrate living and nonliving components for novel device applications;" and (3) biomimetics, building mechanical devices that mimic the abilities or structures of living beings, particularly insects.[19] Combining insects and nanotechnology promises a whole new kind of cyborg creature, remote controlled and deployable for surveillance in the literal form of the fly on the wall. The controlled biological systems concept is an instrumentalization of life using state-of-the-art technology, making it a genealogical descendent of the biological testing programs conducted during aboveground nuclear testing. The deployment of the pig in the 1950s was also a "real-time collection of information" through

Figure 5
Robot insects designed at Los Alamos National Laboratory. (Photo courtesy of Los Alamos National Laboratory.)

biological organisms, exploring the impact of the exploding bomb, rather than the environmental effects of nuclear production. In post–Cold War Los Alamos one can find work on vivisystems—environmental sentinels in the form of tritium-sniffing bees—and also the biomimetic project of engineering robots with insect-like abilities. For example, Figure 5 presents robot insects—a mechanical dragonfly and butterfly—designed at Los Alamos as part of a wider project to think about the social uses of "mechanical" life forms (Shroyer 1998:159). The militarization of the honeybee is, therefore, only one aspect of a new "state of nature" on the Pajarito Plateau put in motion by the Manhattan Project.

Whereas specific animal forms are being deployed—and reinvented—to shape environmental politics in post–Cold War Los Alamos, a more subtle aspect of the Manhattan Project has been to transform regional human populations into radiation monitors. Activist groups spent much of the 1990s pushing for environmental impact studies and increased regulation of the laboratory, helping to produce a cross-cultural regional dialog about the environmental consequences of nuclear weapons research at Los Alamos. Concurrently, LANL scientists, Pueblo representatives, and officials from the Bureau of Indian Affairs each began conducting independent tests of air, water, soil, plants, and animals in the region, not only to define the level of risk to Pueblo citizens living adjacent to the laboratory but also to confirm the accuracy of LANL science.[20] The Pueblos of Jemez, Cochiti, Santa Clara, and San Ildefonso have begun training new generations of youth as environmental scientists to prepare them to take over responsibility for monitoring the environmental effects of the laboratory. By the end of the 1990s, communities throughout the region—LANL scientists, Los Alamos community members, Native Americans, Nuevomexicanos, and antinuclear activists—all claimed the title of "environmentalist," maintaining deeply felt, if asymmetrical, investments in the Pajarito Plateau. However, although each of these populations is committed to preserving the regional ecology, their cultural understandings of that ecology are construed on radically different terms (see Masco 1999, in press).

Life within northern New Mexico's nuclear economy is not simply a political or imaginative project. As New Mexicans began to take an increasingly public interest in LANL's environmental standing in the 1990s, many also played the unwitting role of environmental test subjects throughout the Cold War. New Mexicans did so at two levels: first, as workers at the laboratory who were monitored for radiation exposures on the job, and second, as regional populations who (often unwittingly) participated in the Los Alamos Tissue Analysis Program, an effort started in the 1950s to track radiation exposures via tissue sampling. In the late 1990s, relatives of 407 individuals who had tissue samples taken during autopsies in Los Alamos and regional hospitals brought a class action lawsuit against the laboratory.[21] The multimillion dollar settlement acknowledged that informed consent was not received from family members during these autopsies. Workers in the laboratory as well as residents of Northern New Mexico have thus been part of a larger environmental monitoring project for decades—similar to the bees—but, in this case, their own bodies have been placed in the role of "environmental sentinel." In this sense, tracking radionuclides through the biosphere and specific bodies in Northern New Mexico has become an expanding project for all concerned. The medical knowledge produced by these efforts, however, remains partial and controversial. The fourfold elevated presence of thyroid cancer in Los Alamos discovered in the 1990s might simply be an effect, for example, of the intensity of the screening regime in Los Alamos hospitals (Athas 1996). Nevertheless, although the long-term health effects of nuclear production at Los Alamos remain controversial at the level of technoscience, there is no doubt of the effect they have had on the social imaginations of northern New Mexico. Illnesses throughout the region are attributed to the laboratory, revealing another aspect of the nuclear reinvention of nature.

Conclusion

While interviewing Los Alamos employees who believed their health had been damaged on the job, I was told repeatedly about a videotape reported to document hazardous work conditions at Area G. For these workers, the videotape held the promise of standing as evidence in future legal proceedings, offering a means of making visible to the outside world the everyday practices that were usually shielded by gates, security, and the power of the nation-state. A former Area G worker, who was concerned about his health and did not believe in the veracity of the cumulative radiation badge measurements recorded in his Los Alamos medical file, invited me to view the videotape in his home. As I watched, I was confronted with a complex textual record of mutation. The videotape was originally made by Los Alamos personnel to document efforts to consolidate space at Area G for the accruing nuclear waste from laboratory operations. The banality of worker job descriptions is soon ruptured, however, when a tractor accidentally punctures a partially buried barrel of nuclear waste. The narrative then shifts from recording the formal statements of workers during the handling of the ruptured barrel to informal moments with the work crew playing to the camera. Eventually, the multiracial workforce splits along racial lines, as the white program managers don anticontamination gear to test the drum for radionuclides while the Nuevomexicano and Pueblo workers remain in normal work clothes. The manual labor of digging up and moving barrels of radioactive waste takes place underneath the deep blue New Mexican sky with a ferocious wind that completely covers workers in dust from the site. My host claimed that the dust from the waste site might well have contaminated workers, and then explained to me how easily the radiation monitors could be turned off at Area G to allow such exposures to go unrecorded.

The videotape reveals the difficult work conditions and physical labor needed to move drums of nuclear waste, but the novel presence of the camera also becomes central to the recording: The workers not only do their jobs but they also mug for the camera. Midway through the video, my host interrupts to tell me that he knows what happened to Karen Silkwood, the Kerr-McGee whistleblower who died mysteriously in a car crash in 1974. Her organs were sent to Los Alamos for analysis as part of the tissue registry program but were then mysteriously lost. He tells me that her organs were placed in a laboratory refrigerator, which subsequently failed and was then dumped at Area G, packed full of the damaged organs of U.S. nuclear workers. Area G becomes, in his presentation, not merely an ongoing health threat to current workers but also, quite literally, a grave, a site where the human evidence of radiation exposures is buried as industrial waste. He hopes that the videotape can help reveal this fact, documenting for an outside world the ongoing biological sacrifice of nuclear workers. Twenty minutes into the videotape, the scene shifts to the office spaces at Area G, where the camera operator discovers and then plays with the mirror function on the video camera to produce a series of special effects. For the next 20 minutes of videotape, he entertains his fellow workers—by giving them a third eye, or merging their foreheads into giant mutant forms, or giving them tails, while laughing hysterically at the visual results. The videotape that begins with the serious work of nuclear waste disposal has shifted to a literal discourse of mutation, one that visually transforms each Area G worker into a monstrous being. The Area G workers I spoke with focused more on the official acts documented in the first half of the videotape than on the cultural logics and fears revealed in the second half. But the videotape records not only the everyday practices at Area G, the brute work of moving nuclear waste around and the precariousness of containment, but also a surreal form of nuclear play that shows workers not as potential mutants but as present ones—linked by tails, misshaped heads, and multiple eyes.

The Area G videotape ends on an equally jarring note, as it cuts from the play of mutation at the nuclear waste site to a garage somewhere in the northern Rio Grande Valley, where a Nuevomexicano relative of the camera operator (who has taken the camera home) stands stiffly and without emotion in the center of the screen, playing ranchero music on an accordion. This eruption of the nonnuclear everyday into the narrative of Area G is a reminder of the multiple cultural worlds informing life in northern New Mexico that are linked both formally and informally to the nuclear project at Los Alamos. The Area G videotape reveals the radical transformation of the region into a nuclear economy: It documents the burying of nuclear waste on the plateau, permanently transforming the ecology of that space. It also documents the mobilization of whole communities that are now devoted simply to monitoring and working with the nuclear waste produced by the U.S. national security regime, and ultimately, it demonstrates the fears of mutation that permeate workers' psyches, underscoring the psychosocial effects of living within a nuclear ecology. These forces are not static but, rather, highly mobile, making it impossible to discuss the regional effects of the Manhattan Project without taking into account how material realities fuse with sociocultural logics and nuclear fear. A political ecology of the bomb that investigates the interaction between regimes of nature reveals the American nuclear project to have been ecologically transformative and multigenerationally productive: It has reinvented the biosphere as a nuclear space; transformed entire populations of plants, animals, insects, and people into "environmental sentinels"; and embedded the logics of mutation with both ecologies and cosmologies. The giant cinematic ants of 1954 have, in other words, been replaced now by far more subtle and serious forms of life defined by the ambiguities and dangers of inhabiting specific radioactive spaces within mutant ecologies that now present an ever evolving biosocial, political, and ethnographic terrain.

Notes

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1. The United States heavily censored images of the effects of the bombs on Hiroshima and Nagasaki. See Braw 1991, Goldstein et al. 1997, and Lifton and Markusen 1995. Fear of radioactive contamination from the Bravo test created panic throughout the Pacific, leading government officials to send individuals as radiation monitors in full protective gear to fish markets in the United States armed with Geiger counters to test the safety of the food supply.

2. For critical analysis of atomic popular culture during the era of aboveground nuclear testing (1945–63), see Boyer 1994, Franklin 1988, Henriksen 1997, Evans 1998, Weart 1988, and Shapiro 2002.

3. Radiation standards also assume a kind of universal national subject. The cultural diversity of northern New Mexico, which includes quite distinct land use as well as access to health care, challenges such a formation; see Masco 1999, 2002, in press; Basso 1996; Ortiz 1969; and Briggs and Van Ness 1987.

4. On the concept of the "risk society," see Beck 1992. For work on nuclear risk societies, see Kuletz 1998, 2001; Petryna 2002; Lifton 1991; Garb and Komarova 2001; Gerber 2002; Gusterson 1996; Fusco and Caris 2001; Lindee 1994; Advisory Committee on Human Radiation Experiments 1996; Welsome 1999; Makhijani et al. 1995; Gallager 1993; and Dalton et al. 1999.

5. A recent study by the U.S. Government Accounting Office on radiation standards, for example, concluded, "U.S. regulatory standards to protect the public from the potential health risks of nuclear radiation lack a conclusively verified scientific basis, according to a consensus of recognized scientists" (2000:4). For a history of radiation standards, see Walker 1999 and Schull 1995; for analysis of human radiation experiments, see Advisory Committee on Human Radiation Experiments 1996; for studies of "toxic discourse," see Beck 1992; Buell 1998; Davis 1993, 1998; Edelstein 1988; Fortun 2001; Peluso and Watts 2001; and Vyner 1988.

6. Although the same could be said of many industrial pollutants, and certainly there has been no pristine state of nature since the advent of agriculture and animal husbandry, the global nuclear economy does represent something new. For the first time, the effects of industrial transformation are both worldwide and nationalized through a discourse of state security. The result is that each nuclear effect speaks not only to state security but also to experiences of national belonging or alienation. As Jean and John Comaroff have noted in their study of "alien-nation" in South Africa, the deployment of nature is often used "as alibi, as a fertile allegory for rendering some people and objects strange, thereby to authenticate the limits of the ('nature') order of things; also to interpolate within it new social and political distinctions" (2000:36). In this case, the effects of a nuclear economy are simultaneously material, social, ecological, and political—state sponsored and embedded in everyday life. See Raffles 2002 for a remarkable discussion of the linked social and ecological forces involved in the production of Amazonia.

7. Latour (1993), for example, argues that scientific discourse has traditionally relied on a purification process whereby nature is ideologically reproduced as external to human intervention, making the act of scientific research inseparable from its authorizing mechanisms. On the value of the cyborg to contemporary social theory, see Haraway 1991, Downey and Dumit 1997, and Gray 1995.

8. On the human and environmental costs of nuclear production, testing, and waste storage see Advisory Committee on Human Radiation Experiments 1996, Dalton et al. 1999, Gallager 1993, International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research 1991, Makhihani et al. 1995, Schwartz 1998, and Welsome 1999.

9. In addition to marking the effects of the exploding bomb on the body of the pig, Operation Plumbbob included a series of experiments for controlling atmospheric fallout: Shot Rainier, for example, was the first contained U.S. underground detonation (enabling the U.S. underground test regime of 1963–92). Although containing fallout was an experimental concern for the test series, the immediate project behind each nuclear detonation (or "shot") was to increase U.S. nuclear war fighting capabilities.

10. Operation Plumbbob also involved a series of experiments to "harden" the human body against the effects of the exploding bomb. Flashblindness experiments were conducted, in which volunteers tested a new high-speed electromechanical shutter on goggles (in hopes of protecting Air Force pilots who would be fighting a nuclear war). Concerned that troops would panic at the first sight of a nuclear explosion, the DOD also ran an experiment designed to test how soldiers would respond to seeing an atomic blast for the first time. During shot Galileo, 100 soldiers were exposed to the exploding bomb, and then asked to perform certain drills, such as assembling and disassembling their rifles, to test response times (U.S. Defense Nuclear Agency 1981b:21).

11. Pueblo Nations maintain cultural and, in some cases, legal claims on the land held by the laboratory, and much of the laboratory's workforce comes from the descendents of Spanish colonizers who have more than a 400-year history in the region. Thus, although all communities have an investment in LANL for employment and maintain concerns about

regional environmental and health effects, these are mediated by different cultural logics and legal positions within the United States.

12. For related work in the anthropology of science, see Fujimura 1996; Gusterson 1996; Haraway 1997; Helmreich 2000; Latour 1988; Martin 1994; Petryna 2002; Rabinow 1996, 1999; and Redfield 2000.

13. See the U.S. Department of Energy's (2003) Long-Term Stewardship Program mission statement at http://lts.apps.em.doe.gov/mission.asp, accessed October 15, 2003.

14. For ethnographic investigations into the aftermath of environmental disaster, see Petryna 2002, Kuletz 1998, and Fortun 2001.

15. For analysis of environmental laws and the U.S. military complex, see Dycus 1996 and Ehrlich and Birks 1990. For recent efforts to incorporate environmental concern into the definition of national security, see Dalby 2002. For an analysis of the environmental justice movement in the United States, see Shrader-Frechette 2002.

16. For analysis of Area G environmental contamination, see Hollis 1997; and U.S. Department of Energy 1995a, 1995b, 2001.

17. For information about plutonium and tritium contamination from nuclear research at Los Alamos, see Graf 1994; Los Alamos National Laboratory 1994, 1995.

18. See the DARPA "Controlled Biosystems" website at: http://www.darpa.mil/dso/thrust/biosci/cbs/objectiv.html, accessed October 15, 2003.

19. See Defense Advanced Research Projects Agency 2003; also Revkin 2002; Stone 1999a, 1999b; and the U.S. Army Center for Environmental Health Research "Environmental Sentinels" homepage: http://usacehr.detrick.army.mil/envsen2.html, accessed October 15, 2003.

20. Within the first year of cooperative agreements signed between four neighboring Pueblo Nations and LANL in 1992, environmental testing at the laboratory markedly increased: In 1993, LANL scientists collected 11,500 environmental samples and subjected them to 215,000 tests for contaminants—an increase of approximately 40 percent in samples and 70 percent in tests from the previous year (Los Alamos National Laboratory 1994, 1995).

21. For information and legal briefs related to the Class Action settlement on the Los Alamos Tissue Analysis Program, see http://www.kelleysettlement.com/, accessed October 15, 2003.

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ABSTRACT *A political ecology of the nuclear age developed through a theorization of "mutation" interrogates the contemporary terms of radioactive nature in New Mexico. As an analytic, the value of "mutation" is its emphasis on multigenerational effects, enabling an assessment of biosocial* *transformations as, alternatively, injury, improvement, or noise. Cold War radiation experiments, the post–Cold War transformation of nuclear production sites into "wildlife reserves," and the expanding role that biological beings play as "environmental sentinels" in New Mexico are all sites where concerns about "species" integrity may be articulated in relation to radioactive nature.* [radiation, mutation, ecology, science studies, New Mexico]