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Survivors and scientists: Hiroshima, Fukushima, and the Radiation Effects Research Foundation, 1975–2014

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Abstract

In this article, I reflect on the Radiation Effects Research Foundation and its ongoing studies of long-term radiation risk. Originally called the Atomic Bomb Casualty Commission (1947–1975), the Radiation Effects Research Foundation has carried out epidemiological research tracking the biomedical effects of radiation at Hiroshima and Nagasaki for almost 70 years. Radiation Effects Research Foundation scientists also played a key role in the assessment of populations exposed at Chernobyl and are now embarking on studies of workers at the Fukushima Daiichi Nuclear Power Plant. I examine the role of estimating dosimetry in post-disaster epidemiology, highlight how national identity and citizenship have mattered in radiation risk networks, and track how participants interpreted the relationships between nuclear weapons and nuclear energy. Industrial interests in Japan and the United States sought to draw a sharp line between the risks of nuclear war and the risks of nuclear power, but the work of the Radiation Effects Research Foundation (which became the basis of worker protection standards for the industry) and the activism of atomic bomb survivors have drawn these two nuclear domains together. This is so particularly in the wake of the Fukushima disaster, Japan's 'third atomic bombing'. The Radiation Effects Research Foundation is therefore a critical node in a complex global network of scientific institutions that adjudicate radiation risk and proclaim when it is present and when absent. Its history, I suggest, can illuminate some properties of modern disasters and the many sciences that engage with them.

Keywords

Atomic Bomb Casualty Commission, dosimetry, Fukushima, Hiroshima, nuclear energy, nuclear weapons, Radiation Effects Research Foundation, radiation risk

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The Fukushima nuclear disaster, which began in March 2011, has had wide-ranging effects. It galvanized global awareness of risks of nuclear power (Caldicott, 2014; Committee on Lessons Learned, 2014; Lochbaum et al., 2014; Perrow, 1984, 2013). It undermined public trust of key institutions in Japan, as government and electric company leaders misled the public about what was happening (Birmingham and McNeill, 2012: 92–102; Bricker, 2014). It disrupted the lives of more than 2 million residents in the region and led to the complete and permanent evacuation of some areas (Haworth, 2013). It also generated novel forms of citizen science, including an ambitious program that started on Twitter to map radiation levels in soils across Japan and the do-it-yourself collaborative cleanup programs in the city of Koriyama in Fukushima Prefecture.[1] It can be expected to haunt the region, and the planet, for decades to come. Decontamination and contamination both continue, every day, with highly radioactive water flowing into the Pacific Ocean daily, and soil being scraped up, often by landowners themselves, to be stored indefinitely in plastic bags, parking lots, fields, and roadsides.[2] The financial, social, biomedical, political, and environmental impacts of the still-in-process meltdowns at the Daiichi plant are daunting to contemplate.

The disaster also animated a deep and painful historical connection, as a ‘third atomic bombing’ of Japan. This phrase was used by Hiroshima atomic bomb survivor Keijiro Matsushima in a lecture to young diplomats at the Peace Memorial Museum in the summer of 2011: ‘When I heard the news of the accident at the nuclear power plant in Fukushima, I was stunned. It seemed as though the Japanese people were experiencing the third atomic bombing, after Hiroshima and Nagasaki’ (Tashiro, 2011). Many others linked Fukushima and Hiroshima, as scenes of devastated towns were compared to photographs of Hiroshima after the bombing. The atomic bomb survivors had long been advocates for the elimination of nuclear weapons but silent on nuclear energy. Fukushima changed that. Atomic bomb survivors’ groups became, for the first time, vocal in their opposition to Japan’s nuclear energy policies. ‘Is it Japan’s fate to repeatedly serve as a warning to the world about the dangers of radiation? I wish we had found the courage to speak out earlier against nuclear power’, survivor Masahito Hirose told the *New York Times* in August 2011 (Fackler, 2011).

Nuclear issues pose classic problems of trust, authority, and expertise in Science and Technology Studies (STS) (e.g. Lakoff, 2010; MacFarlane, 2003; Hecht, 2010, 2012; Nelkin 1971). Nuclear issues are also scientific at both ends – made by science and to be solved by science, in the terms first outlined by Beck (1992) in his influential analysis of the *Risk Society* (pp. 160–164). The sciences at the front end are elite physics, chemistry, and engineering, and the sciences at the back end, when the consequences have to be tallied, include messy, slow epidemiology, psychological and social work with devastated survivors, and even the work of political scientists and field biologists (Møller et al, 2012).

This article is about that messy scientific work at the chaotic end and about the people – experts and survivors – who participate together in making the biomedical knowledge that comes from disaster (cf. Ottinger and Cohen, 2011). I explore the history of a scientific institution, the Radiation Effects Research Foundation (RERF) – the successor to the Atomic Bomb Casualty Commission (ABCC) – that studies radiation risk in the survivors of the atomic bombings at Hiroshima and Nagasaki (Lindee, 1994, 1999, 2003). Its research is commonly referred to as the ‘gold standard’ for radiation exposure studies.

Research at the RERF has documented the impact of radiation exposure on rates of leukemia, solid tumors, cardiovascular disease, and many other conditions (Folley et al., 1952; Preston et al., 2007; Shimizu et al., 2010). The RERF results are trusted internationally because of the large number of study subjects, the mix of men and women and all ages, the unselected quality of the sample (not only workers for example), the relatively high exposures of those subjects, the extensive work put into calculating estimated radiation doses, and the comprehensiveness of follow-up studies (International Commission on Radiological Protection (ICRP), 2007; United Nations Scientific Committee on the Effects of Atomic Radiation, [2006] 2008; Valentin, 2003). RERF scientific staff have been consulted in the wake of every radiation accident since the 1970s. Its scientists played a critical role in planning long-term studies of populations exposed at Chernobyl, and they are now engaged with studies at Fukushima – in 2014, RERF was appointed to study the most heavily exposed workers at the still-dangerous nuclear plant.

Trusted as a guide to international radiation protection standards, the RERF scientific program has also been criticized for its inattention to low-dose risks. The linear, non-threshold hypothesis, which guides exposure limits for patients and workers, posits that even extremely low radiation exposures have negative biomedical effects, although the rarity of those effects makes them difficult to find, even in laboratory studies on experimental organisms. The hypothesis is a precautionary way of understanding radiation risk, grounded not in robust data, but rather in logic. The failure of the RERF to focus in any significant way on the potential effects of low-level residual radiation on early entrants, of black rain exposure, and of internal exposure from the ingestion of radioactive materials has been repeatedly criticized by those at risk and by some members of the scientific community. Survivor and physicist Shoji Sawada, retired from Nagoya University and the Representative Director of the Japan Council against A&H Bombs (Gensuikyo), has proposed that the RERF has engaged in a 'cover-up of the effects of internal exposure by residual radiation from the atomic bombing of Hiroshima and Nagasaki' (Sawada, 2007: 58). A December 2014 article by a group of RERF scientists responded to the long-standing criticism that RERF staff had long ignored possible effects from exposure to black rain (Sakata et al., 2014). Earlier, British physician Alice Stewart criticized ABCC–RERF scientific work on related grounds, judging it a poor guide to low-dose worker exposure risks (Stewart, 1982; Figure 1).

The RERF is, therefore, both trusted and not trusted, both believed and disbelieved. Its data are persuasive to some and incomplete to others. This status is in some ways unremarkable in networks where long-term environmental risks with known but uncertain health effects are being studied after a chaotic disaster (see Dowty and Allen, 2011; Frickel, 2004; Fortun, 2001; Shostak, 2013). Those who study human populations exposed to radiation sometimes lament that the public is more afraid of radiation at any dose than of other environmental risks that are equally or more dangerous.[3] Yet, critics of nuclear energy complain that scientists underestimate or underplay radiation risk, perhaps because they are 'in the pocket' of the nuclear industry (Grossman, 2012, 2014).

The survivors of both the bombings and the meltdowns have been exposed to a form of environmental contamination that can be known to them only through technical expertise – only through the testimony of scientists. As Kuchinskaya (2013) has observed, 'radiation is not directly perceptible to the unaided human senses. People cannot see,

Figure 1. ABCC/RERF facilities on Hijiyama Hill. Used with permission of RERF.

hear, or feel radiation. Their senses register nothing. As a result, formal representations become doubly important in defining the scope of what is considered dangerous contamination' (p. 78). Those formal representations are technical products, research articles, international reports, and charts of dose-response curves.[4] This quality of radiation risk – its manifestation only in scientific inscription – may play a critical role in public fears and responses.

At the STS Forum on the 2011 Fukushima/East Japan Disaster, held at the University of California at Berkeley in May 2013, the organizers proposed that it was important to extend the social scientific and humanistic understanding of disasters and the disaster sciences with a goal of developing strategies of engagement with the wider disaster studies community.[5] My work on the RERF is an effort to engage with this STS project through historical analysis of the decades-long struggle to map scientifically the health consequences of radiation exposure in Japan. I characterize the atomic bombings as the first techno-scientific disaster – produced by elite physicists – and propose that an analysis of some practices and policies of the RERF can have a general relevance to our understanding of the scientific management of chaos. I suggest that dosimetry calculation is a fundamentally humanistic exercise critical to all risk assessment; disaster epidemiology can produce different forms of biological citizenship, as at the RERF, and the sharp divisions often posited between military and civilian dimensions of knowledge do not stand up to historical scrutiny.

First, dosimetry. Like all disaster epidemiology, the work of the RERF has depended on reconstructing a relatively short sequence of events in excruciating detail. The need to calculate the risk status of every individual survivor independently makes disaster epidemiology both imaginative and historical. Dosimetry – the post-hoc estimation of exposure – is a central practice of disaster risk assessment. Dosimetry might benefit from perspectives from STS, which attend to questions of situated knowledge, varieties of expertise, and the legitimacy of citizen science (Broman, 2012; Brown, 2007; Collins, 2014; Frickel and Hess, 2014).

Disasters are also often places where governments, institutions, and individuals are apportioned blame (e.g. Vaughan, 1996). Laetita Atlani-Dualt (2013) has pointed out that disasters can be understood as 'collective constructs in which the operational (rescue, life-saving, reconstruction), the discursive (qualification, explication), and the symbolic (commemoration, construction of heroes, assignment of guilt, demands for reparation) are all at play – and interplay' (p. 54). The elements of blame and guilt may produce forms of trust and distrust linked to citizenship, as expert claims about biology and medicine are trusted or not trusted based on the national identity of the scientist – his or her citizenship (see Boudia, 2007). Institutional structures can even perform this kind of citizenship when they require that scientists with specific national identities be appointed to particular roles (as at the RERF). In the 21st century's climate of heightened global risk, when most people live in complex technological systems that are vulnerable to catastrophic failure, public mistrust in a crisis can exacerbate every other problem. My historical case suggests that attention to the scientific authority vested in citizenship can be relevant to disaster planning.

Finally, my account tracks the mongrel nature of militarized and civilian sciences as they have operated in radiation risk networks since 1945. The mixture of state interests, elite science and technology, and corporate investments found in the rise of nuclear energy in Japan is implicated in many other high-risk technological systems. While atomic bombs originally justified the creation of the long-term ABCC/RERF study, by the 1970s, the risks of nuclear power plants became crucial to continued public funding. Industrial interests in Japan and the United States sought to draw a sharp line between the risks of nuclear war and the risks of nuclear power, but the work of the RERF (which became the basis of worker protection standards for the industry) and the activism of atomic bomb survivors have drawn these two issues together. This is so particularly in the wake of the Fukushima disaster, Japan's 'third atomic bombing'.

RERF is therefore a critical node in a complex global network of scientific institutions that adjudicate radiation risk. This article explores its history with an eye to a rich STS literature relating to risk and controversy, nuclear culture, disasters, and citizen science. My case also involves emerging coalitions among different at-risk groups, as bomb and meltdown survivors have become allies. People affected by the Fukushima disaster have now joined cause with Marshall Islanders, Chernobyl area residents, atomic bomb survivors, and other exposed survivors. Together, these exposed populations and the scientists who study them capture nuclear history as it plays out in the vulnerabilities of the human body.

Creating the ABCC

In 1945, both Japanese and Allied experts immediately recognized the importance of studying surviving populations in the two bombed cities. Shortly after the August 1945 bombings, reports in the international press of survivors with mysterious symptoms led to an Allied medical survey of populations in the two cities. This initial work was conducted under tragic conditions, just as the Occupation began awkwardly to establish control of Japan (Braw, 1986). It resulted in a 1946 'Joint Commission' report that laid out a rationale for a long-term medical study of those who had been exposed to the atomic bombs. Japanese scientists and physicians, meanwhile, had already begun collecting data in the two cities, recognizing that the exposures there posed unusual and possibly novel risks (Lindee, 1994; Neel, 1994; Neel and Schull, 1991; Schull, 1990, 1995).

The Joint Commission's report led President Harry Truman to approve a longer term plan for a biomedical study of the survivors, to be organized and overseen by one of the most prestigious scientific organizations in the world, the US National Academy of Sciences (NAS). Funding would come from a federal agency that came to be widely mistrusted, the US Atomic Energy Commission (AEC), successor agency to the Manhattan bomb project. The 'shotgun' wedding of the NAS and the AEC created what was in some ways a vexed alliance. Tensions frequently erupted, especially in the early years of the project. The two institutions had very different cultures and goals, and NAS scientists often challenged AEC policies. Meanwhile, the Japanese scientific community interested in radiation effects in the survivors was sidelined. Until the Occupation ended in 1952, allied censorship prevented Japanese scientific, journalistic, or literary publication about the bombs. People all over the world debated the morality and impact of the bombings, while public discussion was banned in the country directly affected (Braw, 1986). By March 1948, a formal alliance with the newly created Japanese National Institutes of Health (JNIH) was forged. The JNIH role made the project a 'joint' one, though exactly what that meant in practice was subject to (significant and contentious) further negotiation. Even after censorship ended, the Japanese scientific community had relatively limited access to data collected about the A-bomb victims, as United States officials tried to control public perceptions of radiation risk. The Government of Japan only contributed about 10 percent of the total budget each year until 1975, and scientific leadership at the ABCC always came from the United States (Douple et al., 2011; Lindee, 1994; Neel, 1994; Schull, 1990).

One of the most important triumphs for the developing ABCC was the inclusion of a survey about survivor status in the 1950 Japanese census. People who had been exposed to the bombs were 'hibakusha', a social category that was by no means desirable. Employment and social discrimination against survivors were widespread, as they were believed to be unlikely to be good workers (i.e. sickly, at risk for cancer and other conditions) and unlikely to be good marital partners (at risk for genetic effects in their children though genetic effects were never found). The numbers of self-identified survivors rose gradually in the post-war years, and the data from the 1950 census facilitated the creation of a core population of survivors around whom ABCC research could be structured (Douple et al., 2011; Putnam, 1998; Shigematsu, 1998).

In 1955, the Francis Committee, chaired by Thomas Francis Jr. of the University of Michigan, proposed a research structure that has endured into the present and is widely credited with facilitating a strong scientific program. Francis was a virologist and epidemiologist, who reported on influenza in the 1940s, and played a role in the development of flu vaccines. His committee's key recommendation was that the ABCC establish a fixed study population based on the 1950 census. This made possible systematic, long-term epidemiological studies of a ‘Master Sample’ from which all subsamples could be drawn. The proximally exposed sample at Hiroshima and Nagasaki eventually totaled 71,900 people, including in-utero exposed; the remotely exposed in the two cities numbered about 30,000; and the controls, the unexposed sample, numbered 40,000. The goal, then, was to follow the precise health experiences of about 150,000 people, in two cities, ‘forever’ through studies of life span, adult health, mortality in the next generation, and pathology (Putnam, 1998; Schull, 1995; Shigematsu, 1998). This was a plan to study the survivors and their children until they died. Eventually, a large collection of frozen biosamples, now stored at the RERF on Hijiyama Hill, has extended the possible time frame. The work of the ABCC–RERF has involved, and still involves, one of the largest populations studied for the longest time in the history of epidemiology.

With this in mind, the transition from ABCC to RERF constituted a critical moment in the creation of a new politics for atomic bomb survivor studies. Reconfiguring funding and control made the ABCC both more Japanese and more global. This change coincided with a new emphasis on the relevance of the data collected in Japan to the growing nuclear power industry in the 1970s – and the eventual role of the RERF in studies at Chernobyl and Fukushima – thus positioning RERF to be a broader institution than ABCC, working in a more complex nuclear world.

‘ABCC is dead. Long live ABCC’

In early 1969, ABCC Director George Darling proposed that the relationship between the ABCC and the JNIH be reassessed so that Japanese scientists and institutions could become more equal partners in the project. The ABCC’s core incentive was financial: the project had become too costly. From 1963 to 1973, the budget of the ABCC more than doubled, even though the staff declined by 300 people (staff in 1951 was 1,063; in 1962, 980; and in 1972, 680). Meanwhile, Japan was contributing significantly less to the project than the United States: in 1972, the United States contributed 1.25 billion yen, and the Japanese only 74 million. The value of the dollar in relation to the yen also was falling, and the ABCC was operating with deficits.[6]

A 1969 meeting in Tokyo, intended to lead to a firm agreement, initiated only a 4-year discussion of possibilities and informal proposals.[7] In late April of 1973, Japanese officials became more open to the idea that the Government of Japan should play a more active financial and scientific role in the ABCC. At a meeting in Tokyo that brought together representatives of the AEC, NAS, Japanese Ministries of Foreign Affairs, and Health and Welfare, Japanese officials affirmed an ‘equal participation principal’.[8] They again deferred a commitment on actual support and stated that they could not contribute significantly to the 1974 budget, but Americans involved in the negotiations sensed progress. ‘Reduction in Force’ threats seemed to be affecting Japanese responses (most of the employees at the ABCC were Japanese) and there was even some public criticism within Japan of the government’s ‘evasive’ responses to US overtures for a greater Japanese commitment and a matching increase in Japanese control.[9]

Spofford English, a chemist who worked for the AEC, was a key negotiator at this stage. English proposed to the Japanese three options for the future of the ABCC.[10]

Two involved transferring ABCC employees to the JNIH, which English likely knew would not appeal to the Japanese. The third involved the creation of a ‘new, autonomous, non-profit research institute, incorporated under Japanese law, funded and governed equally by Japan and the United States’. English’s argument in favor of sustaining the ABCC in a new form called up the specter of a nuclear energy accident:

> Japan has one of the most rapidly expanding nuclear power industries in the world and Japan will need this information which is being derived from this program, as well as from many other programs of both of our countries, to insure to their own Japanese people that the nuclear energy programs of Japan are safe.[11]

He expressed the consensus that the program ‘should be continued for 20–25 years’ (the ABCC and now RERF have had an ever-receding sunset horizon since the 1950s, always about 20 years away).

Meanwhile, on a different front, the AEC was trying to leverage its cooperative work with the Japanese nuclear power program to persuade the Government of Japan to support a reconfigured ABCC. A proposed deal to sell Japan $320 million worth of fuel for new nuclear power stations was linked to Japanese support for the ABCC.[12] This was an ironic trade: energy technology and supplies would be provided to Japan in exchange for support for the scientific research that would help evaluate and control the new risks posed by the nuclear technology.

In April 1974, when the government of Japan authorized an appropriation for the ABCC for another year, Darling wrote ecstatically to biophysicist Detlev Bronk, then the former president of the NAS (1950–1962), ‘ABCC is dead! Long live ABCC (by whatever name)!’[13] The name of this new institution was indeed still unclear, the central issue being whether it would include a reference of any kind to the atomic bomb.

One of the first proposed names was ‘Institute for Radiological Studies’, which was suitably non-military.[14] The name ‘RERF’ was initially opposed by the Japan Radiation Research Society and the Japan Science Council because it placed ‘the A-bomb under cover’ compared with explicit mentions in ‘ABCC’ and ‘A-Bomb Effects Research’ (JNIH, Health and Welfare Ministry)’.[15] One diplomat reported to NAS President Philip Handler that in Tokyo, there was ‘considerable consternation in the nuclear and nuclear-medical communities over the [RERF] name. It is felt to be too all-encompassing’. Those who studied radiation effects from non-military sources (medical irradiation) apparently did not want competition from the RERF because ‘it has in the past been implicit from ABCC’s name that its studies were constrained to the effects of radiation from the atomic bombs upon Hiroshima and Nagasaki survivors and their offspring’. And the non-medical nuclear community, that is, utilities, ‘would like to remain at arms’ length from all aspects of radiation effects. They are concerned over a weakening of the association between radiation effects and atom bombs, fearing a stronger association with nuclear power will result.’[16]

Consumer activist Ralph Nader, emerging at that moment as a leading opponent of nuclear power (his anti-nuclear group in the United States then had about 200,000 supporters), would visit Hiroshima:

> Nader's purpose in visiting Japan – particularly his much-publicized stop in Hiroshima – is to attempt to draw a strong relationship between nuclear energy and the atom bomb survivors. The response of the nuclear community is to attempt to strengthen, rather than weaken, the association between radiation effects and bombs, and to disassociate nuclear power from the unhappy aspects of nuclear radiation.[17]

But nuclear power was indeed the main justification for sustaining the costly research program on the atomic bomb survivors. By the 1970s, the survivors had become surrogates not only for American civilians threatened with nuclear attack but also for workers, local residents, and anyone at risk from a nuclear power plant accident.

In December 1974, a final agreement was reached. It called for the establishment of a new 'RERF' to be jointly sponsored by the United States and Japan. The closing ceremony for the ABCC was held in March 1975, in Hiroshima. On 1 April, RERF was inaugurated.

Trustworthiness via passport: The citizenship credential

The nationalities of leadership at the new RERF were negotiated in advance. While most of the employees of the old ABCC had been Japanese, scientific control of the organization was wholly centered in the United States. Most of the leadership roles at ABCC were held by US scientists, and until 1959, many publications appeared only in English. Indeed, some scientific overseers of the ABCC in Washington D.C. seemed to fear that Japanese scientists would be biased in their risk assessments: because the victims of the disaster were predominantly Japanese, this thinking went, Japanese scientists would be likely to see more risk than others (Lindee, 1994). On the other side, some Japanese critics believed that the US scientists at the AEC-funded ABCC routinely minimized radiation risks in order to reassure the public about both nuclear weapons and nuclear energy.

This legacy of mistrust shaped negotiations regarding the new RERF. The incorporation documents carefully parsed national identities in the leadership of the new group. A draft proposal in 1974, for example, stated that the RERF Chairman and the Vice Chairman had to be from different countries. The final articles of incorporation ratified these arrangements at various levels, requiring that the RERF have an 'equal number of Councilors having Japanese nationality and US nationality'. The Executive Councilor and the Vice Executive Councilor had to be 'persons of either Japanese or US nationality, but the positions shall not be held by persons of the same nationality at the same time'. The same was true of the Chairman and the Vice Chairman.[18]

No one in a leadership position could come from any third country, either. Rather, they were to be 'citizens of Japan or the United States of America'. In principle, positions would alternate between the citizens of the two countries 'for every term of office'.[19] For the RERF, this was not merely a Cold War policy. Even the 1995 Blue Ribbon Committee, which assessed the work of the RERF, had membership requirements allocated by both Japanese and US citizenship and by third-country participants alternately chosen by scientists in Japan and the United States. Instead of being chosen and identified solely in terms of expertise and disciplinary training as biochemists, geneticists, pathologists, statisticians, and so on, those appointed to serve on RERF committees needed to have a primary identity as Japanese or United States citizens or as possessing a more neutral nationality inflected by being acceptable either to officials in Japan or the United States.[20] In the 1990s, the Blue Ribbon Panel, reflecting a sense that 'the United States has run out of candidates for leadership positions', suggested 'internationalizing' the candidate pool for leadership at RERF.[21] The binational agreement that created the RERF, however, did not allow this.

Boudia (2007) notes that in 1955, some scientists demanded that a study of radiation risk be carried out by scientists unaffiliated with countries possessing nuclear weapons. Such proposals and policies express an understanding of scientists as nationally located, as claiming authority based on national identity. Petryna (2002) used the term 'biological citizenship' to refer to how those affected at Chernobyl drew on their health status to make claims for state support, social equality, and biomedical resources, as they battled skepticism and indifference in the institutions charged with their care and management. In my account, also engaged with radiation risk and nationalism, the valences are reversed. Citizenship matters not in terms of individuals claiming state resources or rights but in terms of experts from different nations making claims about biological risk. Petryna's citizens draw on their own biology to establish a particular political status. My experts draw on their own political status to make claims about biology. This state of affairs may seem unremarkable, but remarkable in this case is the institutional, international scientific consensus that qualities of citizenship should be configured as credentials.

The RERF quickly began to function as an international training center for scientists drawn from places where nuclear energy posed biomedical risks. It made a transition seamlessly to an emphasis on nuclear energy rather than nuclear war. Scientists from the United States, China, and the Soviet Union/Russia and Ukraine all came to the RERF to learn the critical skills needed to carry out radiation-related research and to understand risk evaluation of radiation hazards.[22]

When Chernobyl Reactor No. 4 exploded in 1986, RERF welcomed four Soviet scientists to Hiroshima for consultations and, in 1990, RERF Chairman Itsuzo Shigematsu was appointed the Chair of the International Atomic Energy Agency (IAEA) and World Health Organization Advisory Committee on Chernobyl. Media reports of severe radiation sickness and malformed infants seemed inconsistent with the known doses for Chernobyl, and RERF data would be marshaled to 'clarify the health status of people in the affected areas'.[23] Shigematsu chaired the International Advisory Committee on Chernobyl and also the critical summary meeting in Vienna of the International Chernobyl Project. In his opening comments, Shigematsu recalled the long struggles over dosimetry at Hiroshima and Nagasaki and emphasized the importance of careful estimation of the radiation dose received by every person included in the biomedical studies. It was estimated that at Chernobyl, 570,000 people were exposed, so this would be a significant program of interviews and reconstruction:

> Otherwise, of course, any attempt at a follow-up study of the health effects of radiation would be meaningless. In fact, it may be no exaggeration to say that *more than half of all the efforts made in Hiroshima and Nagasaki during the past 45 years* to follow up the late health effects of the atomic bomb survivors has been devoted to the dosimetry problem. (Emphasis added)[24]

I turn now to this work, which consumed so much energy and time in Hiroshima and Nagasaki.

Reenacting chaos

As Shigematsu suggested, people who study disasters spend a great deal of time reliving them. They try to reconstruct as much as possible the details of the chaos: the timing, sequence of events, and where everything and everyone was. At Hiroshima and Nagasaki, at the moment of detonation – the critical moment of exposure, in comparison with which all other exposures were trivial – the types and amounts of radiation released and absorbed were not stable, measured, known facts about the world, but rather were frequently recalculated estimations, grounded in technical and social uncertainties and shaped by Cold War secrecy.

At first, details about radiation released by the two bombs were considered technical secrets and the AEC refused to reveal them to ABCC scientists. In 1950, the Washington oversight committee for the ABCC asked Cornell physicist Robert R. Wilson to examine published reports (most importantly Glasstone, 1950) about atomic weapons (both those used in Japan and those tested in the Pacific and the Nevada testing grounds) to make some estimates about probable radiation doses. There was more information available about the implosion-type bomb used at Nagasaki because it had been test fired, at Alamogordo on 16 July 1945 and also at the Bikini test site in the Pacific in the summer of 1946, but the radiation estimates from the tests were not made available to the ABCC. The Hiroshima 'gun-type' bomb was of an entirely different design that had been used only once. It was never detonated again and its radiation yields have therefore generally been more approximate and more dependent on extrapolation from other kinds of bombs. In any case, none of the estimates of radiation from Los Alamos relating to the bombs used at Hiroshima and Nagasaki or to the bomb tests was provided to the ABCC in the early years. Despite being funded by the AEC, the agency charged with investigating the biological effects of radiation had to make do with gleanings and assumptions based on publicly available information. The bomb's radiation impact was a state secret even for a state-supported scientific project. The ABCC's earliest publications, for example on leukemia, used distance from the hypocenter instead of dose to categorize survivors.

Some of the most important data and materials that would have helped with dosimetry also fell victim to post-war secrecy. In the days after the bombings, a team from Kyoto University, led by the physicist Sakae Shimizu, had picked up photographic film from shops and collected samples of such things as sulfur from insulators on telephone poles. His group also directly measured radiation levels in the two cities. They estimated the height of the burst, and, drawing on instruments they built themselves and on calibrated radiation sources prepared at the US Bureau of Standards before the war, they began the process of deciphering how much and what kinds of radiation the bombs had produced. In short, their notes and materials contained the very best, most immediate data collected at both sites. As the Occupation forces seized control of Japan in 1945, everything relating to the work of this team was confiscated. What happened to the materials after this confiscation is still unknown. In 1977, when Oak Ridge National Laboratory health physicist John A. Auxier wrote his frustrated account of these events, the materials had still not been found despite extensive searching. 'It is likely that they are in some file in one of the many record depositories and that someday they will be found. In the meantime, the job that would've been much easier with these records went on without them' (Auxier, 1977: 59). Meanwhile, by 1955, 'the nuclear detonation by the Russians had made clear the absurdity of attempting to classify and keep secret every scrap of information about nuclear bomb radiation' (Auxier, 1977: 18). Finally, serious work on dosimetry could begin.

In October 1952, Japanese investigators began to take detailed personal histories from survivors. Survivors would answer a few relatively straightforward questions – about their location, clothing, and experience, about where they had been, what they heard, whether they felt a blast or heat, and whether they had experienced black rain. Then they would be asked to tell the complete story of what had happened to them. Survivors also took the team to see where they had been at the moment of the bomb's detonation and demonstrated their exact position and location: they re-enacted the moment in physical and embodied terms. Often, a draftsman would make a drawing based on what they said and many of those drawings are preserved at the RERF today. By the end of 1954, 2,000 histories had been completed at Nagasaki and 650 in Hiroshima (Auxier, 1977: 19–25; see also Auxier, 1964, 1965; Auxier et al., 1958).

Anyone who survived close to the hypocenter was inside a building, so understanding buildings was critical. The AEC had construction blueprints for every major structure in Hiroshima and Nagasaki, including every reinforced concrete building, all school buildings, and dozens of factory and office buildings at the Mitsubishi Arsenal Complex in Nagasaki (One-fourth of all survivors who had been less than 2000 m from the bomb survived in this complex). The categories of shielding situations listed included 'in the open', 'behind some building', 'in the open but totally shielded by terrain', and 'shielded totally by a factory building'. There was also a final category, 'fetal exposure' – shielded by a maternal body.[25]

In 1956, a field testing program was established in the Health Physics Division of the Oak Ridge National Laboratory, called Ichiban – 'first', often with the connotation 'best'. Ichiban staged reenactments of the bombings in the Nevada dessert. (Auxier, 1964: ii). The Oak Ridge group worked with the ABCC to develop specifications and drawings for a 'typical' Japanese house, as a part of its planned surrogate bombing of what the group called a 'phantom' Japanese community at the Nevada Test Site. Teams measured dimensions and densities of commonly used building materials in Japan – mud plaster walls, slate, wood siding, tatami mats – and built experimental houses on this desolate landscape to be occupied not by people but by radiation sensors.

The ABCC sent building materials and specifications to the Oak Ridge group, including bamboo, seaweed for stucco materials, roof tiles, and oyster shells. American construction crews then built the Nevada homes (Auxier, 1977: 31). In the tests named 'Plumbob', in 1957, these houses were loaded with 120 sensors and bombed. The resulting analysis of data, which summarized all dosimetry information available at the time, was designated T57D for 'tentative 1957 dosimetry' (Ritchie and Hurst, 1959). Later, cement–asbestos board, made by Johns-Manville, was found to be equivalent in shielding to the Japanese mixture of clay, oyster shell and seaweed wall plaster and the mud and tile roofing, and so from then on tests used 'Japanese' houses made of asbestos board (Auxier, 1964: 8). The desert bombings thus involved radiation analogs of Japanese houses, constructed in terms of materials that mimicked the originals. The Nevada Test Site was a theater in which radiation risk was enacted, with houses made from materials

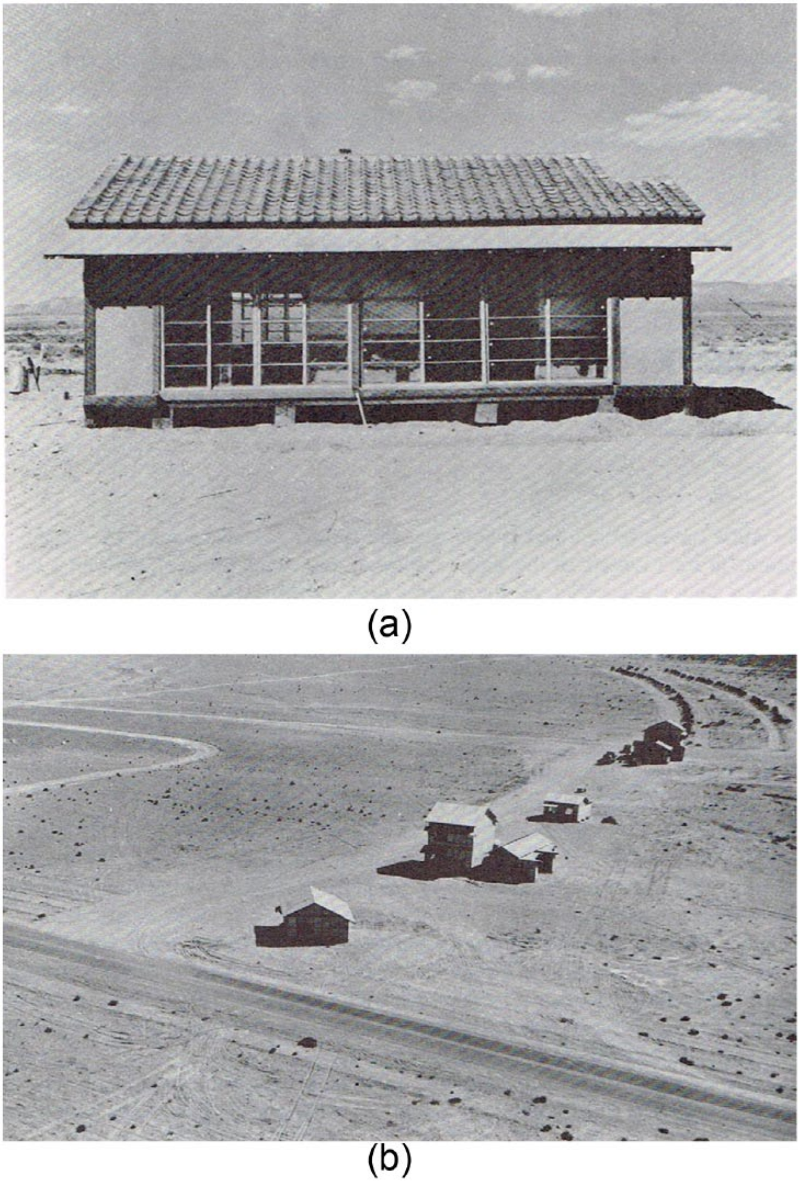

Figure 2. (a) Plumbob Japanese house and (b) analog Japanese houses, from Auxier (1977: 32, 44).

unrelated to life or death in Japan, ‘Japanese’ in only one parameter, shielding capacity. A Nagasaki type bomb then completed the performance (Figure 2).

There were other testing programs at the Nevada site that focused on such ‘phantom’ houses. They included houses much like the new suburban homes of the 1950s in the United States: ramblers and split-levels and two-story brick homes, stocked with refrigerators and canned goods. Photos depicting the US atomic testing program at the height of the Cold War are often disorienting, but the images of these fragile human domiciles, with their sofas and lamps, seem particularly uncanny, in the senses of the word explored by Masco (2006)–representations of a new American modernity, ‘blurring the distinction between the animate and the inanimate and between the natural and the supernatural’ (pp. 28–30). The 2SWF (two-story wood frame) House ‘on the dry lake bed of Yucca Flat’ bombed in Operation Teapot featured living room sofas, plates and cups, even a toilet (Auxier et al., 1958: 41–43). There were no people in these houses when they were bombed, but the houses were occupied by techno-scientific ghosts – future victims of an imagined nuclear apocalypse, represented by sensors that could record anticipatory, calculable damage – cancer, heart disease. As Avery Gordon (2008) asks, ‘how do we reckon with what modern history has rendered ghostly?’ (p. 18). The radiation monitors placed around the rooms in these phantom houses were standing in for phantom human beings, people whose health had already been (or would be) compromised by radiation.

Between the 1970s and 1990s, dosimetry continued to change. Complicating public understanding of radiation risk, the ways of naming and measuring radiation have changed and expanded as well. The measurements through which radiation risk is conveyed have expanded from a simple (if incomplete) metric of rad (radiation absorbed dose) to an international agreement to use Gray (Gy) instead (one Gy is equal to 100 rad). There are other ways of measuring radiation, including sieverts, becquerels, rems, and curies, all having particular technical or medical meanings, and all important in the scientific interpretation of radiation. Meanwhile, the calculations of physicists and others involved in the dose assessments continued to shift based on new quantitative estimates and new interpretations of blast effects. In 1983, RERF’s William J. Schull lamented to a colleague that the genetics program was on the brink of being able to ‘demonstrate that man is not mouse-like in his genetic response to radiation’. This demonstration would ‘make all the work (and the expense) of the past 35 years worth-while! Unfortunately – just when I thought we were close to pinning this down, along comes the dosage reevaluation. We’re in “hold” until we have the new doses’.[26] Somehow dosimetry was never completely pinned down and stabilized. It did not hold still. ‘The problem of estimating the amount of radiation received by persons exposed to the atomic bombs in Hiroshima and Nagaski is still troublesome today, after 20 years of study of the question’, Kato et al. (1966) wrote, and ‘for the present we must be content with this range of uncertainty’ (p. 366).

Calculating radiation doses continues to engage the contemporary RERF, suggesting just how central reenactment is to disaster sciences. In 2014, RERF statisticians Eric Grant and Harry Cullings completed a draft paper that reconstructed the physical maps of Hiroshima and Nagasaki as the cities might have been in the summer of 1945. The maps used to study the survivors for 70 years had been based on pre-bombing US Army aerial photographs. These photos included distortions due to technological limitations of the cameras, tilting to the horizon, how the cameras were held, the kind of lenses used, and the exact height at which they were taken. The overlapping images in the aggregate produced a full but imperfect image. New digital techniques in the 21st century would make it possible to correct these images, to improve the irregularities, recapture some ‘lost’ terrain, and stretch the city visually into a proper geographical format. The resulting veridical map – of a detailed ghost city full of houses and shops gone for 70 years – then had implications for the exposure calculations for each survivor (Cullings et al., n.d.).

Figure 3. Aerial reconnaissance image of Hiroshima before bombing used by the RERF to reconstruct a city long gone. Used with permission of the RERF.

The RERF group placed individual survivors on these new maps, with additional assessments of terrain shielding and the shielding of buildings. Every one of the 93,000 survivors changed position. Survivors had long been placed on the map based on two intersecting numbers on a grid. In the original placements, the last two digits of each number after the decimal point had for convenience been dropped. This had the effect of pushing most survivors essentially directly on to the grid lines. When those extra decimals were added back in, the map changed. People did not move far, but they moved. The changes made the RERF epidemiology group, Grant said, 'more confident' about their assessments.[27]

As this outline suggests, dosimetry and mapping are central to the technical reconstruction of disaster – even 70 years later – and they require a suite of skills that are humanistic, sociological, quantitative, and technical. What happens over a single day can take decades to unravel and interpret. It must be technically and socially relived, through photos, maps, stories, measurements, archive hunts, and explosions.

New maps of contamination

When a tsunami overwhelmed the aging reactors at Fukushima in March 2011, the RERF was immediately in consultation with scientists at Fukushima Medical School. A preparatory meeting for the tentative Fukushima Health Management Study was held at Fukushima Medical University and attended by two RERF epidemiologists. This was followed by ongoing collaborations between RERF and Fukushima Medical

University, including the establishment of a dose estimation panel (like the dosimetry studies for the bomb survivors), and continuing work on enrolling exposed populations in the study, simplifying questionnaires, improving response rates, and making plans for the preservation of biospecimens as part of the study. The long experience of the RERF in planning and sustaining an epidemiological study of this size, length, and complexity is now being leveraged in the Fukushima disaster. A contract to conduct a long-term study of the most heavily exposed group in Fukushima, those who are working to clean up the plant, was awarded to RERF in October 2014. This will involve studying workers who continue to be exposed to high doses of radiation as they try to clean up the reactors. The current roadmap for dismantling the reactors at Fukushima outlines four decades of work.[28] There are and will be many exposed workers.[29]

Fukushima also mattered in Hiroshima and Nagasaki, however, in a different way, as the disaster reanimated old wounds and inspired an activist anti-nuclear energy movement among survivors. Hiroshima survivors reached out to those exposed at Fukushima and began to see a common experience. Fukushima-as-Hiroshima became an important trope in Japan, as survivors and journalists made the comparison. 'How much did we learn from our experiences in the atomic bombings of Hiroshima and Nagasaki?' one survivor said. 'We may have underestimated the horrors that nuclear energy could bring about. The situation in Fukushima, which has been contaminated by radiation, will remain difficult for a long time, just as in Hiroshima and Nagasaki 66 years ago'.[30] The lanterns placed in the river at the Atomic Bomb Dome during the 66th anniversary ceremonies that August included anti-nuclear energy messages.[31] Meanwhile, Nihon Hidankyo, the Japan Confederation of A- and H-Bomb Survivors, with about 10,000 members, made a formal appeal to the Government of Japan to eliminate civilian nuclear power. Hirotami Yamada, Secretary General of Hidankyo's Nagasaki chapter, told reporters that

> the bureaucracy, industry and the media were able to shut our eyes to the danger of nuclear power. We let them fool us, even in this country that was the victim of the atomic bomb. They convinced us that nuclear power was different from nuclear bombs Fukushima showed us that they are not so different.[32]

Sumiteru Taniguchi, Director of the Nagasaki A-Bomb Survivors Council, captured the depth of feeling:

> When the conversation turns to the ongoing crisis at the Fukushima No. 1 Nuclear Power Plant it is as if the floodgates open. Nuclear power and mankind cannot coexist. We survivors of the atomic bomb have said this all along. And yet, the use of nuclear power was camouflaged as 'peaceful' and continued to progress.[33]

Survivors' organizations demanded that the Japanese government provide health care and medical support to those exposed at Fukushima (Goodman, 2014). Their own health care needs had been ignored in the years immediately after the bombings. The appeal for medical care for the Fukushima victims was a powerful way of standing with these new victims of a radiation disaster.

The mapping of the affected regions in Fukushima Prefecture resonates with other mapping projects at Chernobyl and elsewhere:

> The zoning has been revised a few times, resulting in the division of the City into five areas; the difficult-to-return-to area; the not-permitted-to-live-area; the ready-to-be-lifted evacuated area; the specific-spot-recommended-for-evacuation area; and the no-restriction area.[34]

The carefully delimited areas mentioned above are in Minamisoma City, a town formerly of about 70,000 people, now reduced in size, on the coast of Fukushima Prefecture, 14 km north of the Daiichi Nuclear Power Plant. The terrain of this small coastal town has been separated into spaces defined by human absence or presence, future presence and recommended presence, based on levels of radiation that have been officially detected and reported. The categories map how the radioactive materials fell in March 2011 and how they have been moved, reconfigured, rearranged, by rain, wind, and time. Minamisoma City is now a place in kinship with Hiroshima, Bikini, Hanford, Chelyabinsk, Semipalatinsk, Sellafield, and Chernobyl. It has joined a different kind of 'nuclear club', characterized not by military power but by contamination. Just as the atomic bomb survivors found kinship with the Fukushima survivors, so, too, the geography of the Tohoku region in East Japan is now linked to other geographies around the world. Across the prefecture, radioactive soil is being moved and rearranged by human action: landowners and contracted workers and activist volunteers power-wash sidewalks and scrape off topsoil, depositing it in large plastic bags that are then stored somewhere – at the edge of their own property, on concrete platforms or in open spaces near train tracks. These abandoned bags of radioactive soil are temporarily stored at the margins of lived-in spaces. Meanwhile, people live in other margins displaced indefinitely to former parking lots full of government-sponsored temporary housing. Some towns have been abandoned completely. Many others are still in disarray.

Fukushima's is 'not the worst nuclear accident ever but it is the most complicated and the most dramatic', as James Acton of the Nuclear Policy Program at the Carnegie Endowment for International Peace has observed. The Brookings Institute has characterized it as the most costly disaster in history.[35] As the World Bank summary of the impact outlined, the disaster left some 20,000 people dead or missing, with most of the deaths caused by drowning. About 130,000 houses were leveled and 260,000 severely damaged. The areas worst hit were the Fukushima, Iwate, and Miyagi prefectures, and many residents had to relocate from one evacuation center to another as the government expanded the mandatory evacuation zone. Some 82 percent of evacuees changed centers at least three times, and one-third changed more than five times. At the end of 2011, more than 150,000 people had been evacuated, at least 60,000 of whom relocated to other prefectures across the country.[36]

The region of Japan affected by the meltdown is now in a state of 'slow violence', the evocative term proposed by Rob Nixon to describe how environmental damage unfolds and in the process performs inequality (Frickel and Vincent, 2011; Nixon, 2011). Residents hear from scientists at leading, prominent institutions like the RERF that they are not expected to be at risk of long-term health effects as a result of the nuclear meltdown, because for everyone except the workers, radiation exposures are much too low, 'barely above background'. These reports draw on the research with the atomic bomb survivors, on the legitimacy of the detailed dosimetry studies at Hiroshima and Nagasaki, and on the long, careful epidemiology that has been conducted for 70 years. This idea, that no effects are expected, is repeated in many venues by many experts (Boice, 2012). When Fukushima Medical University reported the results of the Fukushima Health Management Survey in September 2014, officials stated, as usual, that no radiation effects were expected – not by the University, not by the World Health Organization, not the United Nation Scientific Committee on the Effects of Atomic Radiation, or the ICRP. All were agreed that there would be no direct health effects from the radiation at this stage, and only a remote possibility of health effects in the future.[37] But damaging effects from radiation are expected by many residents, whose landscapes of identity and history have been traumatically reconfigured by the accident. Whose expectations can and should guide public policy?

In her presentation at a meeting about Fukushima held in Hiroshima in the fall of 2014, Kim Fortun outlined scales of analysis relevant to the immediate management of disasters. These include, she proposed, the public image of radiation (a meta scale: 'Godzilla'), the political domain (a macro scale), the social disruption (a meso scale: evacuation), the intimate medical experiences of each person (a micro scale), and the technical, ecological, and digital analysis of risk and damage.[38] Disaster management now must operate with all these levels in play and to do so often involves complex collaborations rather than one-way statements from scientists about the natural facts. The ICRP economist Jacques Lochard has developed 'Ethos in Belarus' and has also worked with new RERF Chairman Niwa Ohtsura on 'Ethos in Fukushima'. These are social projects that seek 'sustainable improvement of living conditions' for those affected by radioactive contamination. They involve working with the community on a fairly intense level, helping to solve problems household by household.[39] Rethy Chhemm, formerly the Director of the Division of Human Health at the IAEA, has asked experts engaged with radiation risk 'how do we tell a story that makes sense?' More scientific data, he suggests, may not be what is most needed by survivors. 'We lose the battle if we talk only numbers'.[40]

Many scholars have characterized a new modern era in terms of a 'radical break' that occurred around the early 1970s, produced by scientific and technological activities 'for which the planet has become a vast laboratory' (Balogh, 1991; Boudia and Jas, 2007: 319; Centemeri, 2010). [41] In this time frame of a moment of transformation in the 1970s, the RERF seems to be a characteristic type of institution, a site where the structural tensions of a risk society can be seen unfolding in policies and practices, in the everyday life of making new knowledge. RERF provides data that can be leveraged for the reassurance of those survivors who are exposed to radiation. It is also a key node in a system that oversees the 'vast laboratory' of global nuclear energy and its accidents, actual or potential. While I am inclined to see a more radical break in 1945, indeed something new happened for the ABCC as it became RERF:

> The international system for the regulation of radiation risk is simultaneously the result of US foreign policy, international relations in the context of the Cold War, public mobilization against nuclear weapons, criticism and demands for precaution as well as scientific research

> interests and the desire for disciplinary and professional legitimization. The major task, therefore, is to untangle the jumbled threads. (Boudia, 2007: 390)

I hope my account of the emergence of the RERF as a resource for radiation risk management can constitute an untangling of one of those threads, tracking an institution as it evolved from a weapons orientation to an economic orientation, from nuclear fear to nuclear hope, and particularly to the promotion of energy resources critical to Japan, which became a leading user and producer of nuclear energy. Citizenship, dosimetry, and the military–industrial–academic complex play a role in many modern disasters. Knowledge of risk is increasingly dispersed and dappled, like the radioactive materials contaminating prefectures in East Japan. People know different things in different locations, and many observers – activists, scientists, physicians, international radiation risk experts – have begun to ask how STS analysis can help to clarify the issues and problems. Certainly it seems we are obligated to try.

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Notes

1. Both involve forms of what Collins (2014: Introduction) has called ‘default expertise’, stemming from the sense shared by average citizens that experts might be wrong about radiation and risk and that local citizens have forms of expertise that can challenge science. On the Twitter campaign (Safecast), see Yasushito (2011) and http://blog.safecast.org/about/ (accessed 3 January 2015). The cleanup organization *3a* is a more local organization run by Suzuki Yohei, a construction contractor. *3a* makes equipment and techniques available to residents in the area who need help carrying out their own decontamination or testing their soil. There have also been four Citizen-Scientist International Symposia on Radiation Protection since the disaster, at which scholars, scientists, and citizens discussed questions of laws and rights, public information, emergency responses, and so on. See http://csrp.jp/symposium2014 (accessed 12 December 2014). See also the Citizen Science Initiative Japan (CSIJ), http://blogs.shiminkagaku.org/shiminkagaku/2013/02/whats-csij-citizen-science-initiative-japan.html (accessed 4 January 2015), which began before the disaster but which has developed programs on low-level radiation risk.

2. One scientist drew on the data in these reports to reach the conclusion that the leak was probably significant (Kanda, 2013), contrary to the nearly daily reassuring press releases by the Tokyo Electric Power Company.
3. While I have heard this complaint informally from many sources in the scientific community, (it has some qualities of a taken-for-granted fact among scientists who study long-term effects of radiation), it is articulated in published form by scientists only rarely (e.g. Wigg, 2007: 21–25).
4. On the history of radiation protection standards, see Walker (1994, 2000, 2004), also Hacker (1987).
5. https://fukushimaforum.wordpress.com/2012/09/15/nsf-award-for-the-sts-forum-on-fukushima/ (accessed 28 January 2014). For a helpful historical account of the application of expertise to disaster management, see Knowles (2011). Lakoff's (2010) edited volume brings home the new fusion of private and public in disaster management.
6. Philip Handler laid out the issues with some forcefulness in letters to James V. Neel, in the spring and summer of 1973, in D: MED: Com on ABCC: Adv: ABCC Program; U.S. Viewpoint, Review, Archives of the National Academy of Sciences, Washington D.C. (hereafter, NAS). See also, on the budget and the nuclear trade, Gilbert Beebe and Aaron Rosenthal to Philip Handler, 15 May 1973 'Report on Meeting with Japanese re ABCC' in ABCC box 32, folder 'Visit of English, Liverman, Abbadessa, Rosenthal to ABCC April 1973'. In visit of English Liverman Abbadessa Rosenthal to ABCC November 4–17: 1974, NAS.
7. There was a US proposal in January 1972 and there were Japanese proposals in November 1972 and March 1973. Gilbert Beebe and Aaron Rosenthal to Philip Handler, 15 May 1973 'Report on Meeting with Japanese re ABCC' in ABCC box 32, folder 'Visit of English, Liverman, Abbadessa, Rosenthal to ABCC April 1973', NAS.
8. 'Talking Paper', 29 November 1972, Ministry of Foreign Affairs, in Box 32, Dr. Dunham Report of Visit to ABCC 1972, NAS.
9. Gilbert Beebe and Aaron Rosenthal to Philip Handler, 15 May 1973 'Report on Meeting with Japanese re ABCC' in ABCC box 32, folder 'Visit of English, Liverman, Abbadessa, Rosenthal to ABCC April 1973', NAS. On broader cultural tensions in Japan at this time, see Zwigenberg, 2015.
10. English spent most of his career with the AEC, until his retirement in 1976 – just after the RERF deal was reached. He was also a proponent of nuclear disarmament who served on the United States delegations to the United Nations Disarmament Conference in London in 1955 and the Conference for the Cessation of Nuclear Weapons Tests in Geneva in 1959. See his 1981 obituary at http://www.nytimes.com/1981/04/13/us/spofford-g-english-dead-at-65-helped-develop-the-atom-bomb.html (accessed 24 September 2014).
11. Gilbert Beebe and Aaron Rosenthal to Philip Handler, 15 May 1973 'Report on Meeting with Japanese re ABCC' in ABCC box 32, folder 'Visit of English, Liverman, Abbadessa, Rosenthal to ABCC April 1973', NAS.
12. Gilbert Beebe and Aaron Rosenthal to Philip Handler, 15 May 1973 'Report on Meeting with Japanese re ABCC' in ABCC box 32, folder 'Visit of English, Liverman, Abbadessa, Rosenthal to ABCC April 1973', NAS.
13. George Darling to Detlev Bronk (sent to his home in Media PA), 5 April 1974, ASSEM: Life Sciences, 1974, D Med: Com on ABCC: Adv, General, NAS.
14. An 'Institute for Radiological Studies' was proposed in 17 April 1973, letter from Aaron Rosenthal to Philp Handler. Rosenthal said that 'the AEC was receptive to the proposed Charter for an independent, autonomous Institute for Radiological Studies'. Letter in Medical Sciences 1973, Com on ABCC: Adv, ABCC: General, NAS.
15. Translation from *Asahi Shimbum*, 12 April 1975, in Radiation Effects Research Foundation (RERF) General Correspondence (1) NAS 'Conclusion on change of name for RERF to be

carried over? First Board Meeting on 14th' (this story was in anticipation of the first board meeting) RERF Translation Sec – 16 April 1975, in Radiation Effects Research Foundation (RERF) General Correspondence (1) NAS.

16. In 28 March 1975, telegram sent to Philip Handler and Seymour Jablon, to the Sec. State in DC, and to US ERDA in Germantown by Shoesmith, American Embassy, Tokyo. Named recipients: A. Friedman, J. Liverman, J. Whitnah EREDA, Nareco for A. Rosenthal, B. Kropp. Subject: Name of RERF in file labeled 'International Relations, 1975 Internal Organizations, Radiation Effects Research Foundation Proposed', NAS.
17. In 28 March 1975, telegram sent to Philip Handler and Seymour Jablon, to the Sec. State in DC, and to US ERDA in Germantown, Shoesmith, American Embassy, Tokyo. Named recipients: A. Friedman, J. Liverman, J. Whitnah EREDA, Nareco for A. Rosenthal, B. Kropp. Subject: Name of RERF in file labeled 'International Relations, 1975 Internal Organizations, Radiation Effects Research Foundation Proposed', NAS.
18. The RERF Articles of Incorporation are posted at the RERF website, http://www.rerf.jp/intro/establish/index_e.html (accessed 17 February 2015).
19. Translation, Draft Proposal as of 8 November 1974, Act of Endowment of the Radiation Effects Research Foundation. In file, 'International Relations 1974, International Organizations, Radiation Effects Research Foundation Proposed'. Central Files, NAS.
20. The report describing this protocol is posted online at the DOE at: http://energy.gov/sites/prod/files/2014/07/f17/Report%20of%20the%20Blue%20Ribbon%20Panel%20on%20the%20Review%20of%20the%20Radiation%20Effects%20Research%20Foundations.pdf (accessed 12 August 2014). It is also in a file in MS89 Neel 'Blue Ribbon Committee; 1995–1996' in articles of James V. Neel, HAM-TMC.
21. Robert W. Miller discusses this issue in his letter to the Chair of the Blue Ribbon Committee R.H. Clarke, who was the Director of the National Radiological Protection Board in the UK; 12 July 1996, 'Meetings About the Blue Ribbon Panel at RERF; 1996' Folder 2 of 3, Series 1, articles of William J. Schull, HAM-TMC.
22. Akio Awa, 'Training and Collaboration Programs at ABCC/RERF', 13–14 June 1997. MS89 Neel '50th Anniversary Symposium of ABCC-RERF 1997' HAM-TMC.
23. 'RERF Expertise Aids International Chernobyl Efforts.RERF Update: News and Views from the US-Japan Radiation Effects Research Foundation, Vol 2; No. 2, Summer 1990, page 1. See also, report by M. Rosen, Division of Nuclear Safety, International Atomic Energy Agency, Vienna, 'The International Chernobyl Project' in Symposium Report, 13.
24. Proceedings, The International Chernobyl Project, proceedings of an international conference held in Vienna, 21–24 May 1991 for presentation and discussion of the Technical Report Assessment of Radiological Consequences and Evaluation of Protective Measures, p. 17. Available at http://www-pub.iaea.org/MTCD/publications/PDF/Pub884e_web.pdf (accessed 4 September 2014).
25. The full text of a memo written by Kenneth B. Noble on 19 July 1954 is copied on pp. 8–10 of Auxier (1977). The original memo is Noble, 1967 (this is the publication date not the date written) memorandum for the record, in shielding survey in radiation dosimetry study plan, Hiroshima – Nagasaki, USAEC Report ABCC-TR-7-67, the Atomic Bomb Casualty Commission.
26. Schull to Howard Hamilton at the RERF, 11 May 1983, in 'Howard B. Hamilton I:1:8, April 1983, MC No. 66, articles of Howard B. Hamilton, Series 1, Box 1, HAM-TMC.
27. Interview, Harry Cullings, and Eric Grant, Hijiyama Hill, 5 August 2015.
28. http://www.tepco.co.jp/en/nu/fukushima-np/roadmap/images/t120730_03-e.pdf (accessed 13 August 2014).
29. The plan is briefly described in 'RERF Responses to the Fukushima Daiichi Nuclear Plant Crisis' Updated 17 June 2015, RERF, at http://www.rerf.jp/fukushimaRERFe.pdf (accessed 29 July 2015).

30. https://fukushimanewsresearch.wordpress.com/2011/08/06/usa-atomic-bomb-survivors-join-opposition-to-nuclear-power/ (accessed 3 January 2015).
31. https://fukushimanewsresearch.wordpress.com/2011/08/06/usa-atomic-bomb-survivors-join-opposition-to-nuclear-power/ (accessed 3 January 2015).
32. https://fukushimanewsresearch.wordpress.com/2011/08/06/usa-atomic-bomb-survivors-join-opposition-to-nuclear-power/ (accessed 3 January 2015).
33. http://www.dailykos.com/story/2014/01/12/1269160/-Japan-s-triple-nuclear-meltdown-spells-triple-trouble-for-mankind-and-we-did-it-to-ourselves# (accessed 3 January 2015). Some survivors, including Toshiko Tanaka, have called for the elimination of nuclear energy around the world. http://www.hiroshimapeacemedia.jp/?p=23991 (accessed 3 January 2015).
34. From the online report of the ICRP Eighth Dialogue Meeting, 10–11 May 2014, 'The Situation and Challenges of Minamisoma-Working Together in the Affected Areas'. Posted at http://ethos-fukushima.blogspot.jp/p/icrp-dialogue.html (accessed on 18 February 2016).
35. http://www.brookings.edu/research/reports/2012/03/natural-disaster-review-ferris (accessed 28 January 2015) See also, Brookings report on the overall impact of the disaster, http://www.brookings.edu/blogs/up-front/posts/2013/03/11-japan-earthquake-ferris-solis (accessed 28 January 2015). http://wbi.worldbank.org/wbi/Data/wbi/wbicms/files/drupal-acquia/wbi/drm_exsum_english.pdf (accessed on 18 February 2016).
36. All from the World Bank summary at page 21 Knowledge Notes, summary http://wbi.worldbank.org/wbi/Data/wbi/wbicms/files/drupal-acquia/wbi/drm_exsum_english.pdf (accessed 28 January 2015).
37. http://www.fmu.ac.jp/univ/cgi/en_meisai.php?seq=27 (accessed 4 January 2015).
38. Her comments were at the First Technical Meeting on Science, Technology, and Society: Perspectives on Nuclear Science, Radiation, and Human Health: The View from Asia. Held 27–28 November, 2014, at the International Conference Center, Hiroshima, Japan, with sponsorship from the International Atomic Energy Agency, Hiroshima University, Nagasaki University, and the National University of Singapore. See program at http://www.hiroshima-u.ac.jp/upload/118/STS.pdf (accessed 30 January 2015)
39. http://cordis.europa.eu/pub/fp5-euratom/docs/ethos.pdf (accessed 30 January 2015); and Ethos in Fukushima, http://ethos-fukushima.blogspot.com/p/icrp-dialogue.html (accessed 30 January 2015).
40. Rethy Chhem is a physician and trained historian, now with the Cambodian Development Resources Institute in Cambodia, but formerly the Director of the Division of Human Health at the IAEA. He was one of the key people in the creation of Hiroshima University's Phoenix Leader Education Program to train the next generation of disaster specialists. See: http://www.hiroshima-u.ac.jp/en/lp/po/ra/ (accessed 30 January 2015).
41. Centemeri's (2010) account of the 1976 Seveso, Italy, disaster and its local and global legacies captures some of the dynamics that are now present at Fukushima.

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