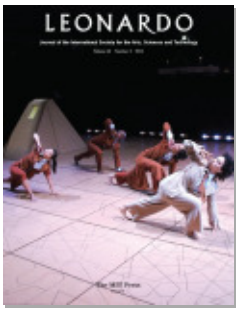
Visual Communication in Times of Crisis: The Fukushima Nuclear Accident

Rama C. Hoetzlein



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ARTIST'S ARTICLE

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ABSTRACT

This paper follows the development of visual communication through information visualization in the wake of the Fukushima nuclear accident in Japan. While information aesthetics are often applied to large data sets retrospectively, the author developed new works concurrently with an ongoing crisis to examine the impact and social aspects of visual communication while events continued to unfold. The resulting work, *Fukushima Nuclear Accident—Radiation Comparison Map*, is a reflection of rapidly acquired data, collaborative on-line analysis and reflective criticism of contemporary news media, resolved into a coherent picture through the participation of an on-line community.

Art has always included visual depiction of conflict and crisis. Katsushika Hokusai's (1760–1849) *Great Wave off Kanagawa* is especially apropos following the Tōhoku tsunami of 2011, which caused the Fukushima nuclear accident. In this work we see a cresting wave about to crash down on oarsmen who remain steadfast in their struggle.

The writer Andreas Ramos describes the image:

> The gigantic wave is a yin yang of empty space beneath the mountain. The inevitable breaking that we await creates a tension in the picture. In the background, a small wave forming a miniature Fuji is reflected by the distant mountain, itself shrunk in perspective. The little wave is larger than the mountain. The small fishermen cling to thin fishing boats, slide on a seamount looking to dodge the wave. The violent yang of nature is overcome by the yin of the confidence of these experienced fishermen. Strangely, despite a storm, the sun shines high [1].

This article considers a visual response to a particular crisis, the Fukushima I Nuclear Accident, following the Tōhoku tsunami, in modern digital terms. Modern artistic responses to nuclear crises, such as Illya Chichkan's *Atomic Love* (2002) in reference to Chernobyl, or Robert Del Tredici's *People of Three Mile Island* (1980), appeal to the viewer with icons constructed through situational or journalistic photography. The present work examines the Fukushima accident in terms of information aesthetics, with a focus on the subjective, human impact of visualization. With the help of on-line communities and public data, I developed a series of maps of radiation levels concurrently with the ongoing crisis, using direct feedback from viewers to support iterative design while events unfolded.

Responding to Crisis

The Tōhoku earthquake and tsunami, which wiped out several towns, including Sendai, Kesennuma, Kuji, Yamadamachi and Rikuzentakata, has led to 15,833 confirmed deaths, 5,943 injured and 3,671 missing (as of 7 November 2011) [2,3]. The scale of the disaster caused major infrastructure failures from transportation to power distribution. The lack of power instigated cooling failures at four nuclear plants: Fukushima I, Fukushima II, Onagawa Nuclear Plant and the Tōkai nuclear station. All four plants initiated a SCRAM or automatic shutdown operation (originally a manual operation performed by the "safety control rod axe man") to insert control rods and halt the nuclear reactions [4]. Although this prevented a runaway reaction, the cores continued to produce high levels of *decay heat* at 6% of nominal operating power, caused by beta decay from radiation still present in the reactor.

In the Fukushima I Dai-ichi reactor, the most significant accident site and the focus of this work, backup systems failed to provide coolant to reduce decay heat. During the crisis, the primary goal was to avoid partial melting of fuel rods, which could expose the public to radiation, as occurred at Three Mile Island (1979), or a core explosion that could throw radioactive material outside the containment vessel, as occurred at Chernobyl (1986). At Fukushima I, in addition to water, generators were flown in to reestablish power for cooling [5]. Despite these efforts, pressure and temperature continued to rise in four out of six reactors on site, resulting in several hydrogen explosions and the manual venting of pressure to the outside air [6].

In the wake of a nuclear crisis, governments respond by instituting evacuations as necessary. In the case of Fukushima I, mandatory evacuations, at first within 10 km, were extended to 20 km (13 miles) on 15 March [7]. National embassies went further in advising their citizens to evacuate areas beyond 80 km (U.S. Embassy and South Korea), and 120 km (Spain), to as far away as Tokyo at 214 km. During these evacuations, lack of information was a serious concern. As one city official said, "It's the responsibility of local governments to grasp the situation of the plant and respond to it. However, no information has been provided to the local governments affected. How can they respond to the crisis?" [8,9]

Our primary source for information in times of crisis is the news media. Yet, due to physical circumstances resulting from a crisis, information may be scarce or unreliable. Messages may be decontextualized, translated across cultural boundaries or manipulated by the news media itself, leaving the public to wonder how to respond correctly. Following the Three Mile Island accident, Dudley Thompson of the U.S. Nuclear Regulatory Commission Office of Inspection stated the engineer's perspective: "Yes, a core meltdown is always a possibility; remote, but . . ." [10]. Despite assurances that a meltdown was not imminent at Three Mile Island, the UPI wire service pub-

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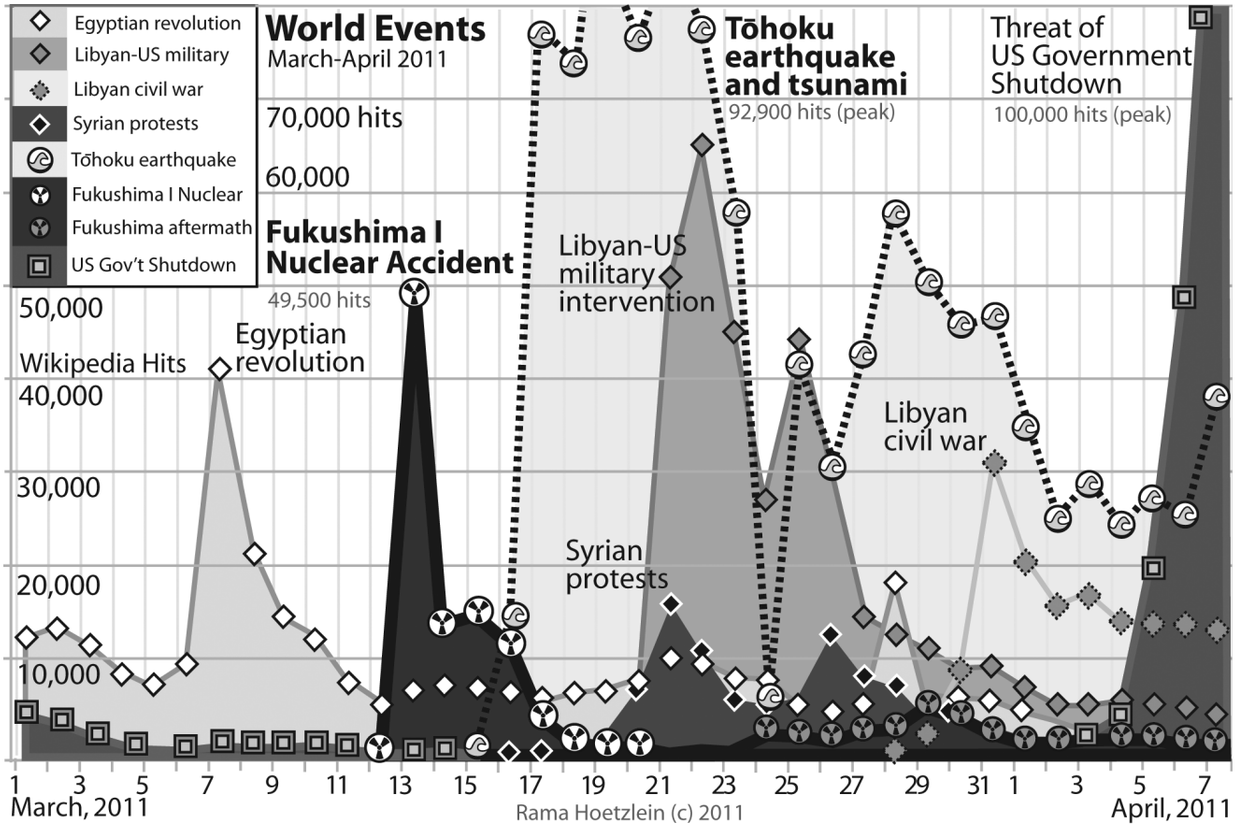


Fig. 1. ***World Events for March–April 2011*****, 1 May 2011. A timeline of world events for March and April 2011, showing Wikipedia hits by topic, reveals that numerous events competed for public attention: (1) the Egyptian Revolution, (2) the Libyan military intervention by the U.S.A., (3) the Libyan civil war, (4) possible shutdown of the U.S. Government, (5) the Japan Tōhoku earthquake and tsunami and (6) the Fukushima Nuclear Accident. High-resolution version available at <www.rchoetzlein.com/theory/fukushima>. Data source: Wikipedia page traffic statistics. (© R. Hoetzlein)**

lished a story titled "TMI Accident Poses the Ultimate Risk of Meltdown," which incited a public outcry, especially in the nearby town of Harrisburg, Pennsylvania, 16 km (10 miles) from the reactor [11].

A central motivation for the creation of *Fukushima Nuclear Accident—Radiation Comparison Map* was a strong desire to determine how those of us outside the evacuation zone should respond. (Are the evacuations in Tokyo warranted? Should those in the U.S. or Europe be concerned about exposure? Can I do anything?) Personally, I found myself unable to function in my daily work as these events unfolded, impacted by both the loss of life and uncertainty over what to do. By 16 March, I reformulated this concern to ask: What is the proper global context for understanding this crisis?

Design and Process

I was inspired by a graph posted on the Wikipedia page for the Fukushima accidents by author "Theanphibian" on 16 March, showing actual radiation levels at the Fukushima site for the first five days based on Tokyo Electric Power Company (TEPCO) data available from 11 March [12]. While the Wikipedia text contained an accumulating list of facts and critical events gathered from news articles, here was a source of real data from the site. It occurred to me that there should be a relationship between the radiation peaks and the explosions, manual ventings and fires written about in the text. I thus sought to make a visual map correlating events to real data.

More importantly, I hoped to ground the map in a contextual theme. Theanphibian's graph was in micro-sieverts (μSv) per hour, while much of the Wikipedia article was in milli-sieverts (mSv) per hour, and many news articles were in mSv per year. A study of 64 news articles for the second iteration of my Fukushima map, described further below, found that most media sources eventually abandoned real radiation doses altogether in favor of reporting "times above normal," without giving any indication of what "normal" represented.

The driving principle used in the overall design of the Fukushima map was the dose equivalent, mSv, radiation received from a dose rate over a fixed time of 1 hour. Although this hides the dose duration, since radiation exposure is cumulative it helps to equalize the relationship between short, high doses—such as in CT scans or those at Fukushima—and long, low doses such as smoking cigarettes (30 mSv/year ≈ 0.003 mSv/hour). I had experimented with plots of dose rate versus dose, but these seemed even more confusing. As pointed out by Edward Tufte, visualizations benefit from "remaining true" to a consistent, driving principle or unit that can be used to frame the graphic as a whole—in this case the dose equivalent of mSv. For more discussion on unit calculations, see my project web site [13].

I created the Fukushima map (Color Plate A No. 1) by writing a Perl script to parse the data. As the original data was in Japanese, I used Google Translate to translate it into English and then applied the script to read the data, convert units and correct for any translation errors (made obvious by the tabular format). I then plotted the data in MS Excel to

generate the basic graphic. Data processing took 2 days of continuous effort, with another 2 days for layout and design.

To create a context for reflection, I needed to gather as much additional data on *other* sources of radiation as possible, including Chernobyl, Three Mile Island, early scientific nuclear accidents, radiation health levels and background radiation by geography and altitude (sources for these are shown on the map). Every event was mapped with respect to dose equivalent, mSv, while also considering where each item belonged and if it was appropriate or misleading. I added these layer upon layer using Adobe Illustrator. Timing was critical, as I wanted to offer this to the community while events were still unfolding. During this time, I did not get much other work accomplished, nor did I get much sleep.

Aesthetic Context

Prior to the era of modern computing, photography provided an effective tool for capturing ongoing events, for example in Larry Burrows's photojournalistic view of the Vietnam War. Image sequences such as Burrows's *One Ride with Yankee Papa 13* (1965) document the drama, suffering and tragedy of war as a narrative occurring in a single day. On the subject of nuclear radiation, Robert Del Tredici's sociological critique *The People of Three Mile Island* (1980) captured the personalities and human drama surrounding this incident. Photographs present visual moments that bring the very real trauma of a remote event to our attention in a way that allows us to briefly share the experience [14].

On 26 April 1986, Igor Kostin took pictures of Chernobyl for the Novosti Press Agency, including aerial photographs salvaged from one roll of film nearly destroyed by radiation. Later, he took photographs of the evacuation of the village of Prypiat [15]. These were to have the most immediate impact in generating a strong public reaction to the dangers of nuclear power, while the aftermath and long-term health effects of Chernobyl were documented more clearly by Alla Iaroshinskaia and others [16].

When multiple news networks present several days of a disaster, we are left wondering how much is reality and how much is a manipulation of our emotions. Where was a particular photograph taken? What were the circumstances? Was this an isolated incident or more widespread? Is the smoke cloud over Fukushima highly radioactive or only slightly so? The lack of regional context in a photograph draws its emotional quality to the foreground, possibly at the cost of balancing other factors. Images make for news but may contain hidden motives.

Artistic, nonjournalistic responses to nuclear disaster focus on the iconography and implicit condition of living in the nuclear age. Illya Chichkan's *Atomic Love* (2002) is a short film showing a man and woman simulating sex while wearing radiation suits, drawing our attention to the paradox of attempts at normalcy in life beneath the shadow of potential harm from technology. Maruki Iri and Maruki Toshi, in *The Hiroshima Panels* (1950–1982), developed a series of folding panels depicting human bodies following the bombings of Hiroshima and Nagasaki as well as other nuclear disasters. These images, using *sumi-e* to create contrast, express and externalize the emotional experience of those directly involved in a nuclear disaster. At the beginning of the nuclear era, such depictions could draw on an empathetic correlation between distant observers and victims, but this connection may be increasingly diluted as the impact and spread of nuclear technology continues and accidents become more common globally.

Disaster simulations present a different kind of photographic evidence. During the Deepwater Horizon oil spill (2010), news media offered multiple, animated, rendered images of the interior of the rig and capping operations. On forums such as The Oil Drum, engineering-minded users shared detailed schematics of the rig [17]. Several years after the 9/11 attacks, Paul Rosen et al. re-created the impact of the first airplane on the North Tower in New York City with highly accurate structural details [18]. Despite their physical accuracy and potential use to structural experts, I would argue that such simulations act on the public more like motion pictures, drawing us into the emotional aspect of the event by temporarily transporting us to the center of the disaster and replaying the moment in a cinematic way devoid of human connection. The first simulation to appear in news media after any nuclear incident is the rendered interior of a boiling water nuclear reactor, which heightens our sense of urgency but also takes our attention away from the needs of real people and the factors affecting their health.

Information visualization offers a systematic context for understanding a crisis. During the Haiti earthquake of 2010, where 316,000 died (20 times the toll of the Tōhoku tsunami to date), Patrick Meier started a joint effort to quickly bring the open-source software Ushahidi on-line for Haiti residents to map the earthquake's effects and human needs [19]. Natural hazards, polluted water, damaged buildings and points for relief provisions were documented throughout the city as a prime example of *crowdsourcing*. Interactive on-line maps aggregated data into a geographic display of the crisis as a whole.

The situation at Fukushima differed in that physical access to the event was restricted both geographically and politically. Residents in a 20-km area were evacuated, most phone services were out and few people were left to contribute to crowdsourcing data on site. Still, news media ran several articles suggesting that crowdsourcing was prevalent in Japan after Fukushima.

I posted the first version of the *Fukushima Radiation Comparison Map* on the Wikipedia page for Fukushima I Nuclear Accidents on 17 March 2011 and also on a blog with commentary. The Wikipedia page itself represents possibly the greatest public effort to document the Fukushima nuclear accident outside Japan, with over 50 users contributing to the article in the first few days. Data for the radiation levels at the plant was released by TEPCO, as required of it by law [20].

Initial reactions to the *Fukushima Radiation Comparison Map* were largely positive. One reader, a teacher, commented on its usefulness as a teaching tool. By the second week, another user moved the graphic to the top of the Fukushima I Nuclear Accidents page.

Tokyo, News Media and Radiation Panic

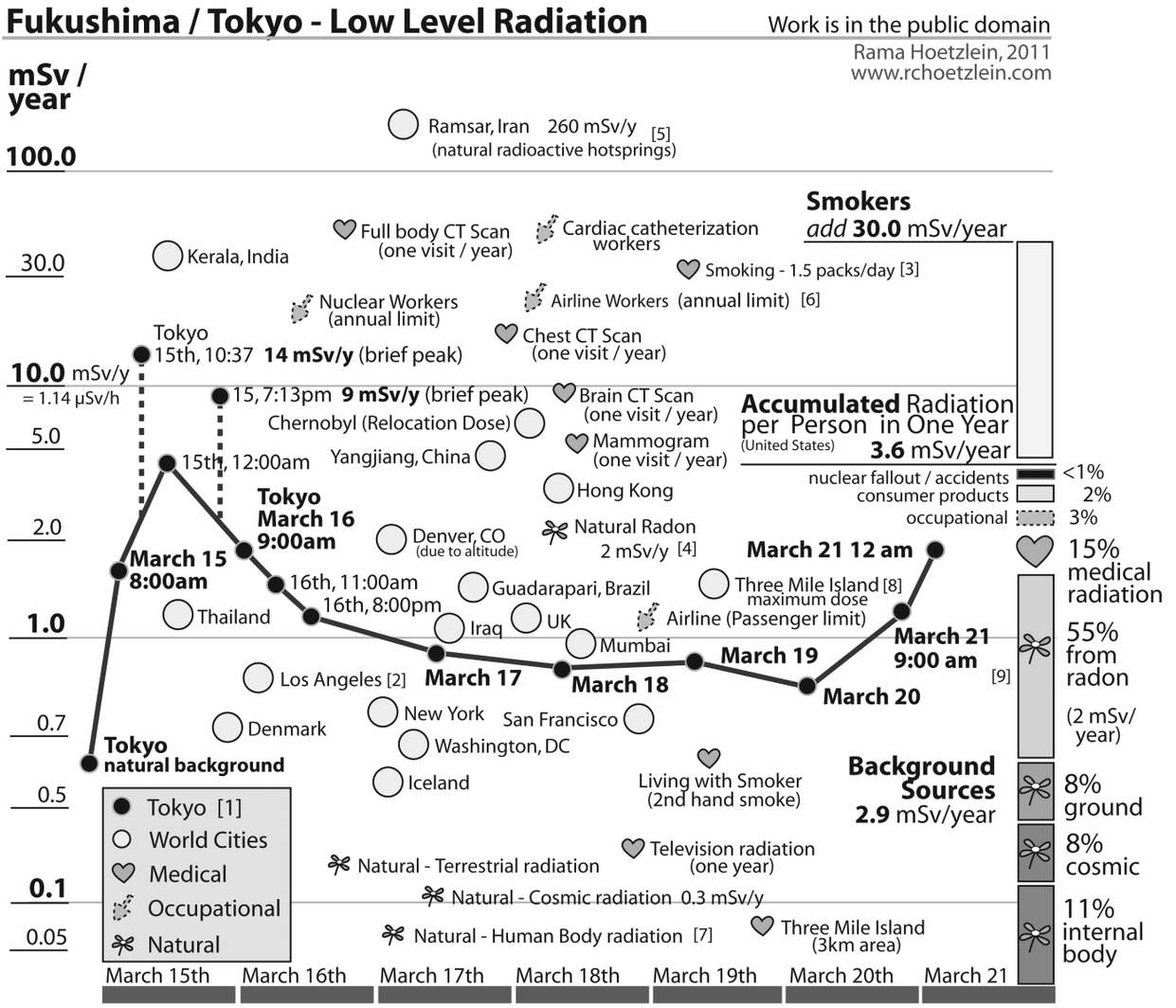
In keeping with the public nature of the data, I decided the map itself should be in the public domain. In some respects, the first graphic was posted too soon, just as radiation levels had reached their peak. Readers wanted to see if the radiation would peak again, indicating a more serious accident, or to see if the levels would gradually decline to bring closure. Interestingly, although the initial readership of the Wikipedia page for Fukushima I Nuclear Accidents topped 49,000 per day on 13 March (see Fig. 1), over the following weeks it dropped off exponentially to ~200 per day as of 8 April. In Fig. 1, based on Wikipedia traffic statistics, we see how the tsunami and nuclear accidents take away readership from the Egyptian revolution (its low point matches the first day of the tsunami), and the Libyan U.S. military intervention takes readership away from both

of these. Syrian protests are drowned out by both the Egyptian and Libyan events. We can also see how focus shifts from the Libyan U.S. military intervention to civil war, and, finally, the possibility of a U.S. government shutdown tops them all in early April.

As the radiation map was released, Tokyo began to see small radiation increases. A large financial institution contacted me to ask if I could extrapolate the implications for Tokyo. Panic in Tokyo was prompted by measurements around the city showing "detectable levels." I developed a separate graphic on Fukushima/Tokyo low-level radiation (Fig. 2) to show that levels in Tokyo, around 1 mSv/year, were in the range of those of other cities around the world (0.5–5.0 mSv/year) and not harmful. Other factors, such as smoking cigarettes (30 mSv/year), are 5 times more harmful than the radiation that Tokyo was receiving, yet numerous articles appeared regarding possible evacuation from Tokyo.

By the second week, fear in the United States was at its peak. In Western media, very minute levels of radiation were presented as a major risk. While levels may be reported as "two times above normal" in a U.S. city, the overall background radiation of the world varies by up to 10 times! News media would mistakenly report levels 10,000,000 times above normal, only to print a retraction stating

Fig. 2. Fukushima/Tokyo—Low-Level Radiation, 27 March 2011. (Created by R. Hoetzlein, 2011. Image in the public domain.) This low-level-radiation map was created to address concern in Tokyo (120 km away) caused by the Fukushima accident. Shown are low-level dose rates in mSv/year for background radiation levels at various cities in the world, compared to changes in Tokyo radiation from 15–21 March, along with individual average accumulated radiation in the United States per year. The results show that Tokyo radiation, while elevated, remained within the background of most world cities outside of Japan. High-resolution version available at <www.rchoetzlein.com/theory/fukushima>.



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levels at 10,000x above normal (at reactor #3), 1850x above normal at a nearby post and 330x above normal for the average person in a "developed country" [21], further confusing readers. Actual radiation units were rarely used after 1 April.

I resolved to create a second, more detailed visualization. Although I knew it must include on-site Fukushima levels, I suspected this would confirm that radiation was gradually declining due to seawater cooling efforts. In the second version of the graphic, I hoped to convey something about regional geographic effects to counter inaccuracies in the news media. Fortunately, Marian Steinbach had had the foresight to start harvesting country-wide radiation data from Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) on a daily basis from the start of the accident and made this available on-line [22]. Although data was missing for Fukushima itself, I could fill this in from earlier sources.

The much greater data available at this point (3 MB) presented new challenges. While I still used a Perl script to parse the data, I developed a custom OpenGL/C++ visualization tool allowing the visualization of geographic radiation data over time as a bubble plot for parts of Japan (including Tokyo, Ibaraki and Fukushima) and for details of Ibaraki Prefecture. I used the tool to create an animated movie of radiation levels, now available on-line [23].

My graphing of radiation by distance was an early source of criticism, since localized ionizing radiation follows an inverse-square law with distance. However, radioactive particles carried in the air are not localized. Although weather conditions are complex, this radiation also decreases dramatically with distance, due to scattering of the particles. To show this clearly, I computed the orthodromic (spherical) distance between radiation measuring stations in the MEXT data to create accurate log-log plots of radiation versus distance, revealing this effect in a new animated movie [24].

The second version of the *Fukushima Radiation Comparison Map* (Color Plate A No. 1) incorporated a sequence of snapshots from the animated movie, in which both the color and the size of geographic dots convey radiation levels according to the overall theme of mSv. The regional map reveals that levels have remained elevated, yet safe, in Tokyo. The inset graphic displays the widely varying numbers presented by the news media. I believe that a great deal of confusion is caused by micro-reporting in textual form; many brief one-paragraph articles over the course of weeks presented radiation levels with little relation to other articles. This visualization allows us to see not only the real levels at the Fukushima site but also their temporal changes geographically. If news media have the resources to produce detailed renderings of reactor cores in a few days, one wonders why they did not produce any coherent information graphics using real time-based data.

On 28 March, I examined 64 news articles published during the first 2 weeks to see how radiation levels had been reported. One article compared lifetime amounts of radiation in 1-km-square areas near Chernobyl (350 mSv/lifetime) to momentary peak radiation levels in the core at Fukushima (400 mSv/hour), without extrapolating lifetime amounts near Fukushima [25]. Overall, the analysis showed that the media had difficulty agreeing on reasonable units for comparison, defining levels of normal radiation and explaining how dosage is cumulative over time.

One of the most surprising outcomes of the map was the discovery that Ibaraki prefecture, an area of over 2 million people 100 km from Fukushima, was being continually exposed to levels above allowable nuclear-worker limits although it was located outside the 20-km evacuation zone. Visualization of data (Color Plate A No. 2) shows waves of radiation passing silently over this area. There was no reporting of this in mainstream news media—although this data was available even in the first week of the crisis.

Visual Engagement in a Crisis

My previous work in visualization presents dynamic overviews of interdisciplinary human knowledge [26,27]. The *Fukushima Radiation Comparison Map* was my first attempt to use information visualization to engage the public directly on a contemporary, developing issue.

Is the assumed objectivity of information visualization retained when dealing with an ongoing crisis? Are artists who engage in independent journalism invisible recorders of passing human moments? Or are information artists more like an on-line media blitz, participating in an information frenzy that draws attention to themselves? These questions should haunt the conscience of any artist addressing an ongoing crisis. Where is the updated crowdsourced map of Haiti showing how much local infrastructure has been rebuilt, or not rebuilt, up to now? Often our efforts in times of crisis rise in proportion to concern for ourselves, only to be forgotten when the longer struggle of recovery begins or when another world event interrupts, as Fig. 1 shows. My hope is that this work remains useful to viewers beyond the immediate crisis.

An epistemic criticism of the present work may be the use of Wikipedia as a venue for expression. Figure 1 suggests that Wikipedia readers, attracted to contemporary events, shift their attention when a new crisis arises. There is also the issue of accuracy and bias. A study by Chesney found that while Wikipedia's accuracy was higher than expected, 13% of the articles contained factual errors [28]. Like any resource, Wikipedia has advantages and disadvantages. Miller, Helicher and Berry found that Wikipedia's ability to quickly generate articles with numerous authors resulted in good coverage of current events [29]. My own experiences with the Fukushima Wikipedia page confirm this. The Wikipedia commentary correlates well with changes in real radiation levels (Color Plate A No. 1). Previously, I have criticized Wikipedia's control structures as being too biased toward non-expert administrative control [30]. To its credit, however, Wikipedia is one of the few resources with commons-based copyrights, which allows the public to share knowledge without restriction to views presented by the news media and without restriction from professional access. In my view, venues outside of these social control structures may be most productive in presenting creative, fact-based reporting on current events of public concern. The number of page hits for Fukushima—49,500 in one day on 14 March—is indicative of its social use in this regard.

My choice of presenting visual works first on Wikipedia rather than in an art exhibition or a news outlet might be viewed as engaging or participating in the forum's public hyperbole and skepticism about current events [31]. I would argue, however, that venues where such irrational discourse (presumably) occurs are precisely where experts should be encouraged to provide more input. To pose an open question: Which is the greatest institutional impediment to raising the level of common knowledge: news media, scholarly media or public media?

When the project began, I imagined the Fukushima radiation map serving as a public grounding point for understanding radiation levels, providing a counterpoint to the news media and

presenting each fact and recorded level as objectively as possible to reduce fears regarding widespread radiation. In fact, the Health Physics Society and others are now using the graphic for teaching. In all cases, these images remain in the public domain, with my time put in freely. The most valuable comments I received came from readers located in Tokyo. They were a reminder that those directly affected by an ongoing crisis are in a different situation relative to those who report or witness it from a distance:

> Your charts are providing useful context and calming the anxiety for many people living here. Thank you for making the time to do this. My Japanese friends are grateful that there are people all around the world who are using their talents to help them [32].

While *The People of Three Mile Island* captured human moments in images, I created this work to convey the need for maintaining proper perspective during ongoing crises, especially for events that happen a great distance from us or outside our cultural bounds. As more traditional media are still essential, I sought not to lessen our emotional connection to others through the obscuration of numbers but to present a subjective humanistic view of information that increases our connection by using that objectivity to remain respectful of others.

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