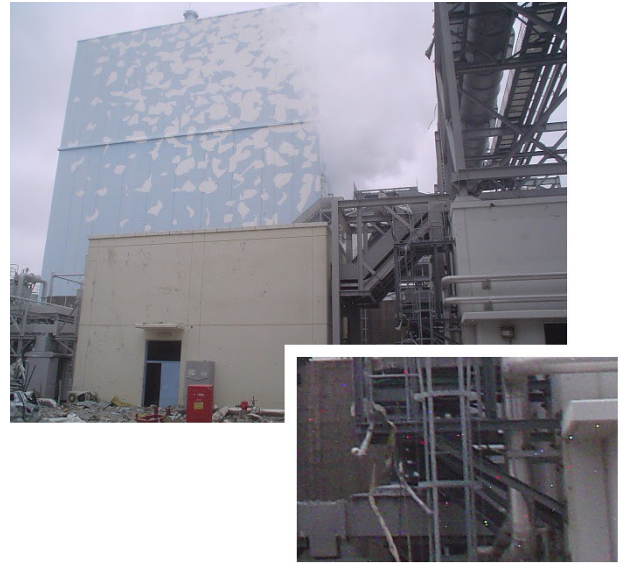


# Photography, Radiation and Robotics Beyond the Visible: Fukushima

Stephen Cornford



On April 17, 2011 “justabystander” sent an image of the exterior of the Fukushima Nuclear Plant to forensic photo analyst and blogger Dr. Neal Krawetz. The seemingly innocuous photograph, taken according to the metadata on March 15, 2011, using a Sony DSC-P32 camera, shows some spurious blotches of colour, particularly visible in the darker areas of the image. The sender asks, “if it would be possible for you to take a good look at the following image, with a focus on the possibility of getting a reasonable radiation count from the light spots.”<sup>[1]</sup> This proposition, that a consumer camera could make an empirical count of radiation at a site of nuclear catastrophe, exemplifies the extent to which contemporary consumer technologies have evolved from scientific instrumentation and are still capable of performing such epistemic functions. But it also preempts what has since become common practice amongst the engineers operating the robots inside the reactors: the routine estimation of radiation intensity “from noise images on the camera screen.”<sup>[2]</sup> These estimates enable engineers to assess the total dose of radiation received by each robot and extract it safely before its circuits succumb to permanent radiation damage.

These sparks of colour in photos and videos published by TEPCO offer a media-radiological echo of the aerial film shot by Vladimir Shevchenko over Chernobyl in 1986 in which, as Susan Schuppli describes, “the disaster had inscribed itself directly into the emulsive layer of the film as decaying radioactive particles transgressed the exterior casing of the movie camera.”<sup>[3]</sup> As a result, Shevchenko’s camera became so radioactive that it had to be buried outside Kiev and Shevchenko

himself died in 1999 as a consequence of his exposure. At Fukushima, the deployment of “self-propelled investigation devices” seeks to mitigate such human costs. Nevertheless, in December 2016, the total storage volume of protective clothing awaiting incineration at the site was 67,000m<sup>3</sup>, giving a palpable sense of the potential future cost to those workers operating the remote cameras.<sup>[4]</sup> At both Chernobyl and Fukushima photographic media have registered the gamma photons radiating from these sites, a visible record of spectral extremes that our eyes cannot see but to which our bodies are deeply sensitive.

For Derrida, there are two distinct types of invisibility. The first is simply that which is hidden from sight. The interior spaces of the Fukushima reactors are now, by necessity, of this order that Derrida terms *in-visibility*: “whatever one conceals in this way becomes invisible, but remains within the order of visibility.”<sup>[5]</sup> The second order of invisibility, which he terms *absolute invisibility*, is “whatever falls outside the register of sight.”<sup>[6]</sup> Although Derrida only explicitly names those vibrations perceptible to other senses, this must also be seen as including the imperceptible portions of the electromagnetic spectrum. In his work on nuclear waste Peter Van Wyck echoes Derrida’s distinction, describing:

*“Two sorts of relation to secrecy: one on the order of the invisible visible – the concealed, the buried, the stealth, hide and seek – and the other on the order of an absolute invisibility – radioactive threats and ecological threats.”<sup>[7]</sup>*

The robotic reconnaissance devices at Fukushima function between these two orders. Their purpose is to mediate the in-visible spaces of the Primary Containment Vessels (PCVs) of Units 1, 2 and 3: to survey the damage and, crucially, locate the molten nuclear fuel. The resulting devices are *all eyes*, some being fitted with as many as seven cameras, and many abandoned for a few hours footage. But, inconveniently for TEPCO, their photo-sensitivity is not limited to an anthropocentrically defined order of the visible, but extends to wavelengths we define as radiation. For Van Wyck, nuclear toxicity is “necessarily outside of the register of sight. It requires a mediation in order to be disclosed.”<sup>[8]</sup> The live video relayed by these robots discloses not only the concealed spaces inside the PCVs, but also the otherwise imperceptible

radiation they encounter there. In both the emulsion of Shevchenko’s film stock and the optoelectronic sensors of the Fukushima robots, the “absolutely invisible” wavelengths of ionising radiation are rendered perceptible.

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On March 26, 2012, TEPCO conducted their second investigation inside the PCV of Fukushima Unit 2. A guide pipe was drilled through the steel-lined concrete walls of the containment vessel approximately 3 metres above the access grating, and an endoscopic camera with an outer diameter of 13 millimetres, a length of 20 metres and a total dose radiation tolerance of 1000Gy was inserted. The operation involved 34 workers each of whom were allocated a maximum exposure dose of 5.29 milliSieverts.<sup>[9]</sup> Unlike the first investigation, two months earlier, from which TEPCO uploaded just a 1 minute digest video,<sup>[10]</sup> this second investigation spawned seven separate videos totalling almost two hours of footage. In them we see the interior walls of the PCV encrusted with yellow deposits over which water flows. The camera is regularly submerged in the base of the containment vessel, bubbles occasionally stream past, presumably released from cooling Corium, the pseudo-elemental term used for the molten metallic mass produced by a nuclear accident. Throughout these videos, speckles of white noise, erroneously reminiscent of dust on film, coalesce with the optical image as a visible register of the radiation. Traditional hierarchies of signal over noise are flattened as these extra-visual artefacts registered by the camera become as informative as the image itself. In a society in which public opinion is produced, manipulated and expressed as much through images as language, this radiological archive reveals the fallacy of the narrative of control and containment.

The most remarkable moments are when the image is overcome by radiation, plunged into a speckled noise field of such intensity that it blinds the camera to the visible light of its surroundings. The white “thermo couple” rod, stretching out in front of the lens throughout, is suddenly shrouded in dense noise enveloping the image. During these

episodes the camera also registers a bright white glow whose source, one can only presume, is molten nuclear fuel, a combination of infra-red heat and extra-visual radiation so intense that it only registers as a whiteout. In TEPCO's now extensive archive, the majority of these remotely operated videos have a singular trajectory, the camera leaves the guide pipe, enters the PCV, explores for a while, moving cautiously over the grating before stopping, either due to mechanical fault or with its communication cable snagged on debris. In this context, what is also remarkable about these videos is the circularity of their narrative. They begin and end inside the guide pipe, the camera and its thermometer appendage return to their point of departure without visible damage.

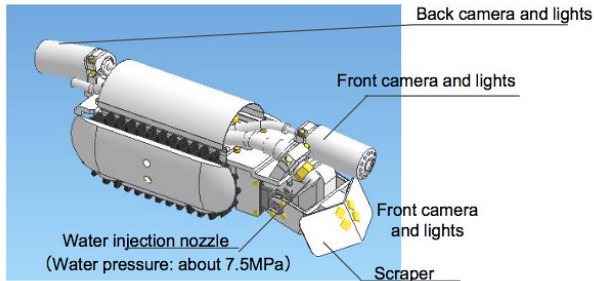
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That the radiation at both Chernobyl and Fukushima has been evidenced photographically is hardly surprising given how thoroughly entangled the histories of radioactivity and photography are. The discovery of the radioactive properties of uranium is usually attributed to Henri Becquerel, who, in 1896, conducted a series of experiments on various fluorescent substances, placing fragments of each onto photographic plates concealed beneath two sheets of black paper, then leaving them in the sun for a number of hours. During this research into fluorescence, Becquerel happened upon the ability of uranium samples to expose the paper, even without the stimulus of sunlight. The developed photographic plates registered a dark silhouette of the radioactive substance, proving their emission of rays invisible to the naked eye yet capable of passing through paper. However, as Fathi Habashi contends, Becquerel's much reproduced radiographs were preceded by some 38 years by experiments conducted by Abel Niepce de St. Victor (cousin of Joseph Nicéphore Niepce) using photographic paper dosed with uranium salts to produce coloured monotone images: "for example, a violet colour was produced when the paper was treated with chlorine, a green colour when iron salt was present, and a brown colour when potassium ferrocyanide was present."<sup>[11]</sup> In the course of his experiments, Niepce de St Victor found that "a drawing traced on a piece of carton with a solution of uranium nitrate ... whether or not exposed before to light, and applied on a piece of sensitive paper prepared using silver chloride will print its image."<sup>[12]</sup> Habashi suggests that it was Becquerel's awareness and repetition of these experiments that led to his

incidental finding. The invisible force of radiation then was not only discovered by Becquerel through its ability to be imaged, but as a direct consequence of photographic research, by its ability to produce colour in photographic processes. The saturated sparks of colour produced in the silicon image sensors at Fukushima are the most recent in a long history of photochemical interactions of radioactive and photographic minerals, reminding us, as Van Wyck writes, that "all images, like the nuclear itself, arise from the ground."<sup>[13]</sup>

This historic entanglement of photography and radiation persists in digital cameras. Image sensors were initially developed for use in: "hostile environments where high levels of radiation are encountered (e.g. outer space imaging applications, particle detection used in beam colliders, nuclear weapons use, plasma physics)."<sup>[14]</sup> The sensors now embedded in consumer cameras are the legacy of the electronic transmission of images from spy satellites and space telescopes, contexts which explicitly require sensitivity to infra-red and ultraviolet frequencies beyond the visible. The ability to render invisible radiation as visible colour was directly constitutive of the image sensor's technicity, however, "optimising the sensor to near perfection in these areas has produced a device that is extremely vulnerable to damage induced by high-energy radiation sources."<sup>[15]</sup> As a result, scientific image sensors are routinely tested for their resilience to various wavelengths of radiation. These tests demonstrate that prolonged exposure leads to a decrease in charge transfer efficiency and an increase in dark current, the former manifesting as an apparent smearing of the image and the latter as an increase in visible noise. It is exactly this double bind of a sensitivity to and vulnerability to radiation, which has defined the ability of remote controlled cameras to so accurately render the extent of the Fukushima catastrophe. Not only are they able to image the absolutely invisible radiation emitted, but the speed with which their vision circuits malfunction evidences the inability of current electronics to function in such environments. For image sensors over-exposed to radiation, therefore, in just the same way as Akira Lippit describes the penetration of the human body by X-rays: "total visibility brought destruction, which is perhaps its condition of possibility."<sup>[16]</sup>

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On February 9, 2017 a Cleaner Robot was sent into the PCV of Unit 2. This “deposit removal device” is fitted with a miniature pressure hose and scraper to clear encrusted waste from the access ramp. In the hierarchy of Fukushima robots the Cleaner Robot is a pawn whose task is merely to clear a path, but,

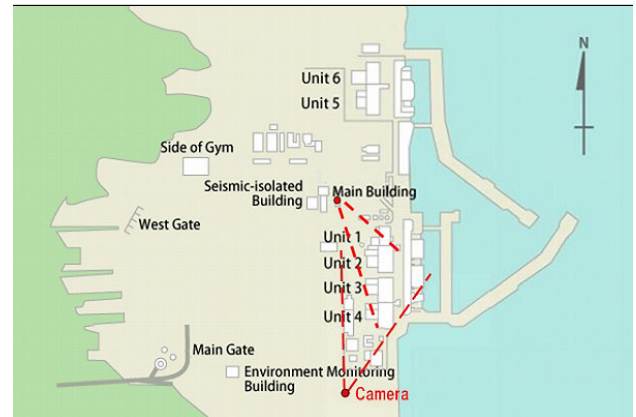
*“after about two hours, the two cameras on the robot suddenly developed a lot of noise and their images quickly darkened—a sign of a problem caused by high radiation. Operators of the robot pulled it out of the chamber before completely losing control of it.”<sup>[17]</sup>*

[Link to Video:](#)

The degradation of image quality evidences the effects of invisible photons. Watching the last minute of the heavily edited footage, the image appears to gradually liquefy, the texture of lumpen deposits clogging the grating becomes indistinguishable from the noise projected by a video codec struggling to find form in the shadows. The spectral excess released from the meltdown of nuclear fuel engenders a meltdown of representation in the machine-eye sent to survey it: a camera malfunction provoked by photonic saturation. The path clearing robot beats a retreat. A press release six days later maintains a now familiar and increasingly implausible techno-solutionist tone.

*“Every step is a new challenge for TEPCO but TEPCO welcomes the challenge. There are lessons to be learned every day. But “technology” such as robots are constantly evolving. And TEPCO will keep moving forward.”<sup>[18]</sup>*

A week later, a Scorpion Robot is sent in to investigate, but in spite of moving further over the deposits than its predecessor, it soon develops a mechanical malfunction on its left-hand crawler belt and is abandoned: “the connection cable was cut and the device was left on the side of the CRD rail not to obstruct further investigations.”<sup>[19]</sup> At what point will the massed malfunctioned robots block the path for further investigation? Will there soon be a robot removal device sent in to nudge its forebears off the rail?



Environmental disasters of recent years are notable for the extent of their exposure. Webcams streaming unfolding catastrophes in heavily compressed, jerky frame rates are becoming the norm, threatening to reduce the gradual ecocide through which we are living to a low-res spectacle. At Fukushima two cameras have been monitoring the site continually from its north and southwestern corners. These cameras also regularly register sparks of radiation, as persistently observed and commented on at several forums and Facebook groups. Some obsessive users seemingly scour hours of footage, screengrabbing individual frames in which sparks are registered. Although these sparks do appear consistent with those registered inside the reactors it is also possible that some of the artefacts observed are produced by cosmic rays, which are omnidirectional, omnipresent and have been shown to produce similar sparks in image sensors.

Cosmic rays were discovered by Victor Hess in 1912, but it was Charles Wilson’s cloud chamber that rendered them visible. Wilson’s intention, following time spent working at the meteorological station on Ben Nevis, had been the creation of a device capable of reproducing the behaviour of

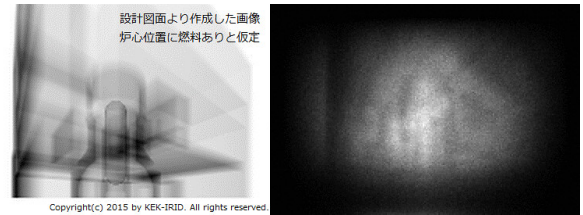
clouds. But, the incidental vapour trails produced by the movement of charged particles through the fine mist precipitated inside the cloud chamber meant that his instrument quickly became central to particle physics. This ability to reveal the tracks produced by the emission of alpha, beta, and gamma from nuclear samples in real time prefigures the condition of Fukushima's robotic cameras.<sup>[20]</sup> Just as uranium's radioactivity was registered visibly by research in another field, cosmic rays were first imaged in a device intended not for meteorological rather than nuclear research. As Peter Galison writes:

*"The cloud chamber, developed under one research programme, would itself establish the boundaries of another, completely different research project. Instruments will not stay put."*<sup>[21]</sup>

But, in one of the most innovative propositions for locating the nuclear debris inside the Fukushima reactors, cosmic rays are no longer a phenomenon targeted for observation and measurement, but have themselves become the measuring instrument.

On March 19, 2015, TEPCO announced it had been trialing a process of muon tomography in order to locate the fuel debris inside Unit 2. Muons are produced by the collision of cosmic rays with particles of the Earth's atmosphere and tend to have the same trajectory as the cosmic ray which produced them. Muons created in this way penetrate deep into the Earth's crust, and have even been recorded as much as half a mile underground. Muon tomography is an experimental process that measures the incidence of muons penetrating a structure, producing an image similar to an X-ray. Two scintillator panels placed 50 cm apart detect incoming muons and calculate their trajectory by comparing their coordinates on the two panels. After a long exposure period these muon strikes can be aggregated to produce an image of their surroundings. As the density of uranium is enough to scatter muons, a shadow is produced in the resulting data visualization, in the same way that the shadow of a bone is seen in an X-ray. Crucially, the plastic construction of the scintillator panels makes them less vulnerable to gamma rays than the solid state image sensors used in cameras, allowing them to be used in high radiation environments for long periods. A 26 day exposure was made at Unit

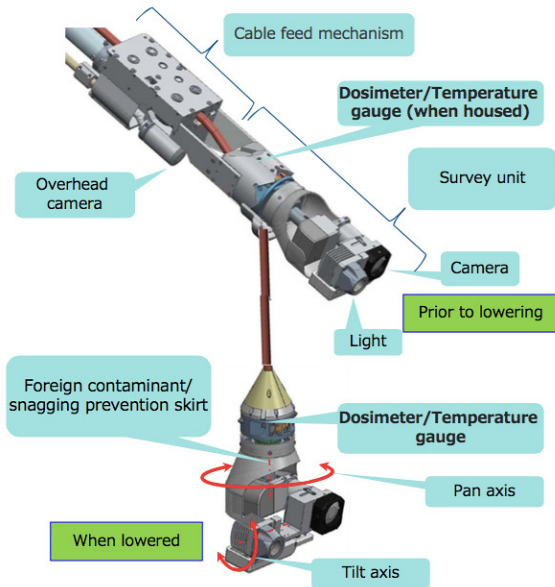
1 between February and March 2015 and the following year a four month exposure was made at Unit 2 between March and July 2016. In the resulting images, one pixel is equivalent to 25cm on the cross-section of the reactor building.



A particle that was once itself the subject of subatomic study is transformed by this process into a photographic phenomenon used to illuminate invisible structures. To adopt the language used by Karen Barad, what was once the 'object of observation' has, in this example, mutated into the 'agency of observation.'<sup>[22]</sup> Nuclear debris, the source of dangerously penetrating particles and photons, is located by the cosmically-induced penetration of all earthly structures by subatomic particles: *the in-visible is located by photographing it with the absolutely invisible*. As Susan Schuppli writes, "such toxic ecologies are only made 'present' to us, that is to say represented to us as fields of experience, through augmented modes of sense perception."<sup>[23]</sup> To see that which is beyond sight we must use what lies beyond light. In this example of muon tomography, Fox Talbot's famous conception of photography as the "pencil of nature" extends beyond exterior, reflected representations to become also the *penetration by nature*. Nature is not only inherently photographic, but also tomographic. If "cosmic rays include every element in the periodic table and are found everywhere in interplanetary space,"<sup>[24]</sup> then a continuous X-ray of everything is always – and has always – been occurring, one which is radically dislocated from the mono-directionality of human perspective and anthropogenic photography. Any structure which is static for long enough is continually being imaged onto all the surfaces around it. We have always been being tomographed, from all sides.

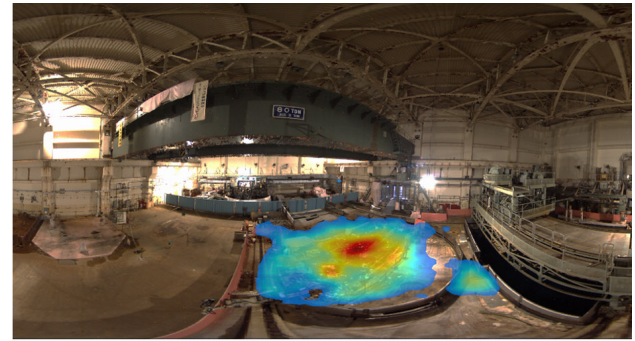
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On January 19, 2018, a “telescopic investigation device” was once again sent into the Unit 2 PCV. The bright yellow plaque which caked the walls six years before has now aged to a rusty brown: every surface appears caked in this substance. Water falls consistently and the now familiar speckled noise is still pervasive. But, apart from the changes evident in front of the camera, this footage is distinct from that six years before in the control exerted over the camera. Where before, the camera’s perspective was reminiscent of a medical endoscope, its motion intermittent and frantic, here the camera replicates the norms of cinematography, panning and tilting as if operated from a tripod. Following Eyal Weizman’s insistence that, “cameras record from both their ends,”<sup>[25]</sup> we can consider the footage not only in terms of what is in front of the lens, but also as to what the camera motion reveals about its operators. For TEPCO, whose inability to contain the radiation or even really adequately account for the fuel, the control exhibited over the camera in this more recent footage at least gives the impression of a calm survey. There are both photons and photos radiating from Fukushima. Gamma photons radiate invisibly, stripping electrons from whatever cells or circuits they embed in, and they will continue to do so beyond the scope of our temporal imagination. Whereas the photos radiating through the internet have a potential more akin to asset stripping, to rapidly deplete the viability of a business model founded on the myopic fallacy of clean nuclear energy. For corporations such as TEPCO perhaps the radiation of images poses the more immediate threat.

Control over the camera operates as a surrogate for control over the site.



On July 8, 2016 Createc, a UK technology company, announced that it had secured “a significant new contract with Mitsubishi Heavy Industries to develop a suite of innovative radiation sensors for use at the Fukushima nuclear site.”<sup>[26]</sup> Createc’s signature product is the N-Visage camera, which combines a 3D laser scanner, gamma spectrometer and spherical 12 megapixel camera. Reading between the lines of the product publicity reveals the specifications of the Fukushima investigation. The N-Visage is described as “the first system aimed specifically at challenging deployments through small apertures” – such as the guide pipe into the Unit 2 PCV. Although TEPCO make no mention of which camera is being used on each robot, it was presumably a bespoke camera of this type used in this investigation, a speculation supported by the release of a revolving 3D model of the Unit 2 PCV assembled from the footage above. The N-Visage completes gamma images in under 2 hours. The edited footage released by TEPCO on January 22nd is just 3’34”, but the gamma spectrograph that would doubtless have been produced is nowhere to be seen. The incidental noise cannot be screened out, but the gamma visualisation is a layer that can just be switched off.

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In Timothy Jorgensen's account of the Fukushima disaster, he attributes the accident to a "flaw in the fail-safe logic" of the cooling mechanism.<sup>[27]</sup> "To be *fail-safe*," he writes, "implies that a machine, instrument or procedure has been designed in such a way that if it should fail, it will fail in a way that will not result in harm to property or personnel"<sup>[28]</sup>. Technical failure and human error are both as inscribed in the design of a nuclear power station as the generation of energy. If, as Peter Van Wyck writes "the accident is part of the endeavour"<sup>[29]</sup> or, in Virilio's formulation, "to invent the sailing vessel or the steam ship is to invent the shipwreck,"<sup>[30]</sup> then to invent the concept of the fail-safe is to invent the fail-safe-flaw, a catastrophic example of which was witnessed at Fukushima. And so with the invention of the nuclear power station comes the invention of the interminable accident (or at least the accident whose duration is inconceivable in the minds of those who witness its event). For Joe Jeonghwan, nuclear energy is the emblematic energy technology of capitalism as they are both sustained by the same illusion of perpetual growth. "Economically" he writes, "atomic energy allows for a type of fantasy about infinite growth."<sup>[31]</sup> However, ecologically, it has created a type of accident which almost *is* infinite.

What we are witnessing with the procession of failed robots, overexposed cameras, and innovative imaging techniques, is the inevitable consequence of the interminable accident: its capacity to become a catalyst for further invention. In the same way that the car crash (an example from Virilio) became the catalyst for the invention of the seat-belt, airbag and ABS (we might even describe the car as now designed around the inevitability of its own crash), the triple meltdown at Fukushima has become the challenge for techno-science. The solutions proposed focus on containment rather than de-escalation. Their priority, in other words, is to maintain the fallacious image of nuclear energy as safe rather than to propose widespread decommissioning and replacement. Fukushima has become a testing ground for robotic technologies and imaging techniques all of which contribute to the normalisation of the nuclear accident. The presumption of future accidents is as much a part of these inventions as the certainty of future car

crashes was for the seat-belt. For Createc, the Fukushima contract is certainly valuable, but the demand it creates for their cameras throughout the global nuclear industry will no doubt prove more valuable in the long run. As Jeonghwan writes "capitalism takes crisis, disaster and death as opportunities for accumulation."<sup>[32]</sup> If the engineers working at Fukushima – and the scientists and technologists worldwide who are carrying out tests and developing cameras on their behalf – are eventually successful in locating and removing the fuel debris from the reactors they will only have succeeded in perpetuating the fallacy that the dangerous effects of nuclear technology can be contained and mitigated technologically. Whereas, as Jeonghwan writes:

*"Radiation leakage management is actually impossible ... if there is to be any management, it would be the management that considers mass killing over generations as normal."*<sup>[33]</sup>

The question then, is less whether the International Research Institute for Nuclear Decommissioning will find a technological solution, but, rather, whether the scale of accidents should be allowed to accumulate, so that "the way the motorway death toll has come to be accepted as a fact of life"<sup>[34]</sup> merely foreshadows the acceptance of a far more extensive, albeit less spectacular, accumulation of fatal bio-accidents in the bodies of those exposed to radiation.

At Fukushima, then, we catch a glimpse of a seemingly inevitable future in which what was once considered "progress" becomes simply a means of trying to survive in an accident which has become permanent, what Virilio termed *the integral accident*. Amid this permanent state of emergency, its relation to invention becomes inverted. No longer is the accident the inevitable consequence of the invention, but instead, all inventions become inevitably targeted at the accident.

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[1]

<http://www.hackerfactor.com/blog/index.php?archives/427-Radiation-Detection.html>

[2] [https://www7.tepco.co.jp/wp-content/uploads/hd03-02-03-004-001-handouts\\_170209\\_01-e.pdf](https://www7.tepco.co.jp/wp-content/uploads/hd03-02-03-004-001-handouts_170209_01-e.pdf)

[3] Susan Schuppli 'Radical Contact Prints' in Kriemann, S & Mertens, H. C. *P(ech) B(lende): Library for Radioactive Afterlife*. Berlin: Spector Books, 2016. p.155

[4] [https://www7.tepco.co.jp/wp-content/uploads/hd03-02-03-001-d170126\\_01-e.pdf](https://www7.tepco.co.jp/wp-content/uploads/hd03-02-03-001-d170126_01-e.pdf)

[5] Jacques Derrida *The Gift of Death and Literature in Secret*, trans. David Wills. Chicago: University of Chicago Press, 2008. p.90

[6] *Ibid.*

[7] Peter Van Wyck *Signs of Danger: Waste, Trauma and Nuclear Threat* Minneapolis: University of Minnesota Press, 2004. p. 28

[8] Van Wyck p.28

[9] [http://www.tepco.co.jp/en/nu/fukushima-np/images/handouts\\_120326\\_07-e.pdf](http://www.tepco.co.jp/en/nu/fukushima-np/images/handouts_120326_07-e.pdf)

[10] [http://www.tepco.co.jp/en/news/library/archive-e.html?video\\_uid=ivcbm60g&catid=61791](http://www.tepco.co.jp/en/news/library/archive-e.html?video_uid=ivcbm60g&catid=61791)

[11] Fathi Habashi 'Niepce de Saint-Victor and the Discovery of Radioactivity'. Available here: [http://acshist.scs.illinois.edu/bulletin\\_open\\_access/v26-2/v26-2%20p104-105.pdf](http://acshist.scs.illinois.edu/bulletin_open_access/v26-2/v26-2%20p104-105.pdf)

[12] *Ibid.*

[13] Peter Van Wyck 'The Anthropocene's Signature' in *The Nuclear Culture Source Book* edited by Ele Carpenter, London: Black Dog, 2016. p.28

[14] James Janesick *Scientific Charge Coupled Devices*. Bellingham: SPIE Press, 2001. p.721

[15] *Ibid.*

[16] Akira Lippitt *Atomic Light (Shadow Optics)*, Minneapolis: University of Minnesota Press, 2005. p.48

[17] [https://www7.tepco.co.jp/newsroom/reports/archives/2017/1375551\\_10469.html](https://www7.tepco.co.jp/newsroom/reports/archives/2017/1375551_10469.html)

[18] [https://www7.tepco.co.jp/newsroom/reports/archives/2017/1377951\\_10469.html](https://www7.tepco.co.jp/newsroom/reports/archives/2017/1377951_10469.html)

[19] [https://www7.tepco.co.jp/wp-content/uploads/hd03-02-03-004-001-handouts\\_170216\\_01-e.pdf](https://www7.tepco.co.jp/wp-content/uploads/hd03-02-03-004-001-handouts_170216_01-e.pdf)

[20] for an example, see: <https://www.youtube.com/watch?v=ZiscokCGOhs>

[21] Peter Galison *Image and Logic: A Material Culture of Microphysics*. Chicago: University of Chicago Press, 1997. p.97

[22] Karen Barad *Meeting The Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* Durham, Duke University Press, 2007

[23] Susan Schuppli 'Dirty Pictures' in *Living Earth: Field Notes from the Dark Ecology Project* edited by Mirna Belina, Amsterdam: Sonic Acts Press, 2016. p.197

[24] Janesick p.724

[25] Eyal Weizman *Forensic Architecture: Violence at the Threshold of Detectability*. New York: Zone Books, 2017. p.38

[26] <https://www.createc.co.uk/createcs-future-brigt-as-mitsubishi-place-order-for-fukushima-sensors/>

[27] Timothy J Jorgensen *Strange Glow: The Story of Radiation* Princeton: Princeton University Press, 2016. p.355

[28] Jorgensen p.354

[29] Van Wyck p.12

[30] Paul Virilio *The Original Accident* Cambridge: Polity Press, 2007. p.10

[31] Joe Jeonghwan 'Between Cognitive Capitalism and Disaster Capitalism: Fukushima' in Kyungwon, M. & Joonho, J. (eds) *News from Nowhere: A Platform for the Future & Introspection of the Present*. Seoul: Workroom Press, 2012. p.52

[32] Jeonghwan p.49

[33] Jeonghwan p.53

[34] Virilio p.13