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In the Shadow of Tomioka

On the institutional invisibility of nuclear disaster

John Downer

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Abstract

The 2011 meltdowns at Fukushima might have falsified long-standing expert assertions that nuclear power is 'safe', yet it has failed to do so. This paper looks at why. It explores two core tenets of post-Fukushima nuclear discourse: (1) that nuclear meltdowns will not occur; and (2) that nuclear accidents are 'tolerable'. In each case, it outlines how accounts of the disaster shield the credibility of the wider nuclear industry; and it then explains why these accounts are misleading. In doing so, it offers a critical perspective on the public discourse around technological risk and disaster. It concludes with a brief discussion of the sociology of denial. Invoking both the agnotology and science and technology (STS) literatures, it argues that it is often more fruitful to temper claims of deception with a recognition of the genuine ambiguities and structural weaknesses of complex knowledge-claims.

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The corporate grip on opinion in the United States is one of the wonders of the Western world. No First World country has ever managed to eliminate so entirely from its media all objectivity – much less dissent.

~ Gore Vidal

Introduction

On the first anniversary of the 2011 Fukushima-Daiichi nuclear accident, the world's media gaze turned briefly to a place called Tomioka. Situated near the ruined nuclear plant, inside the evacuation zone, Tomioka had become a silent radioactive ghost town – a 21st-century Pripyat.[2] Newspapers ran photo essays showing its empty streets, once known for their cherry blossoms, now littered with abandoned vehicles. Weeds grew through cracks in the asphalt. Several journalists interviewed the town's single remaining resident, a 53 year old farmer who had stoically remained to feed the scores of animals that local farmers released before they fled: cows, pigs, and an ostrich named 'Boss'. By then his cumulative exposure to radiation had been enormous. He told reporters he did not expect to live beyond 60 (Harlan 2012; Kennedy 2012).

In the shadow of Tomioka and the many other outsized dramas and terrors occasioned by the Fukushima meltdowns, it would have been easy to conclude that atomic energy had little future. The fact that a single technological failure could be so portentous as to upstage the momentous earthquake and tsunami that instigated it, we might reasonably suppose, ought to have unequivocally exposed a far-reaching failure in the way that advanced industrial societies have come to conceive and manage infrastructural risks. In exposing that failure, moreover, it might have been expected to have killed the political fortunes of atomic energy. Long-standing critics of nuclear power could hardly have looked for a clearer vindication of their fears.

In some spheres, at least, this does appear to be Fukushima's legacy. Japan, for instance, has been gripped by a groundswell of public opposition to atomic power since the accident, which, as of writing (in October 2014), remains powerful despite vacillating political determinations (see e.g. *Japan Times* 2014). Germany, meanwhile, determined to abandon nuclear entirely. It shut down 8 of its 17 nuclear plants in months after the accident, announced a plan to shutter the remainder by 2022.

In most instances, however, dreams of 'nuclear renaissance' live on. Prior to Fukushima, 547 reactors were either proposed, planned or under construction

[2] Pripyat, in the Ukraine, is the location of the Chernobyl reactor – an abandoned town at the centre of a wide 'exclusion zone' around the failed reactor.

throughout the world. A year after the disaster, this number had increased to 558 (Holloway 2012). In February 2012, the US Nuclear Regulatory Commission (NRC) approved licenses to build two new reactors in Georgia: the first such approvals since the Three Mile Island accident in 1979 (Abernethy 2012). The following month it approved two more, this time in South Carolina (Wingfield & Johnsson 2012). Construction began at both sites in March 2013. Around the same time as the NRC approvals, meanwhile, Britain and France signed a formal agreement paving the way for a new generation of reactors in both countries (Press Association 2012). The financing of the UK's first such 'new build' reactor was approved by the European Commission in October 2014. It is to be constructed at Hinkley Point on the Bristol Channel, at a site where, in 2005, the local council rejected proposed wind turbines due to safety concerns relating to detached fan blades (BBC 2005). Simply put, the political credibility of nuclear energy in these countries appears to have 'escaped' from Fukushima, just as it escaped from Windscale in 1957, Three Mile Island in 1979, Chernobyl in 1986, and countless other brushes with disaster over the years.

How the nuclear industry was able to retain its political credibility in such circumstances is the question that motivates this paper. The answer, it will argue, lies in the fact that nuclear experts are consistently able to make compelling arguments to justify why the industry's past failings should not detract from its future credibility. These rationalisations are not always explicit or intentional but their logics are so pervasive that even many of the most critical accounts of the disaster implicitly, and often unintentionally, serve to distance the Fukushima from the wider industry. The discourse around Fukushima renders these arguments in varying ways but they cluster around two central rationales.[3] These are: (1) that the accident was somehow exceptional and will not re-occur. And (2) that the accident was tolerable. The following two sections of this paper will sketch the contours of these arguments in more detail and then critique them in turn. These sections will be followed by a discussion that reflects more widely on the social process of organisational 'forgetting', its contentious relationship to institutional interests, and its under-examined relationship to the epistemology of expert knowledge.

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[3] The paper does not try to separate the accounts of journalists, policy makers, industry experts, academics and regulators, as all are deeply intertwined. Both journalists and policy makers depend on nuclear experts for their information, and the nuclear sphere is characterised by so much movement and interdependency between industry, academia and regulation that it makes little sense to distinguish experts in terms of their vocational loyalties. Industry ties with government, for instance, were evinced when the *Guardian* published a series of internal emails showing that Areva, EDF Energy and Westinghouse worked closely with the British government to downplay the Fukushima accident and avoid setbacks to proposed nuclear power plants (Edwards 2011). Industry ties with publishing, meanwhile, can be seen in ownership structures. In the US, for example, General Electric owns much of the NBC broadcasting network, and Westinghouse owned CBS for many years (Grossman 2011).

One: 'The accident will not re-occur'

The first basic narrative through which accounts of Fukushima have kept the accident from undermining the wider nuclear industry rests on the claim that the accident's causes were either exceptional or remediable, and, hence, will never re-occur. I will cover this argument relatively quickly as I have explored it in more detail elsewhere, albeit in slightly different contexts (Downer 2014a; 2014b). Broadly speaking, however, it is useful to break this claim into three sub-narratives: one that focuses on the tsunami and earthquake; another that focuses on the operation and assessment of the plant; and a third that focuses on the plant itself.

Let us consider these one at a time.

1. *The claim that the external events that precipitated the disaster were unrepresentative and will not return*

Speaking at press conference soon after the accident began, the UK government's former chief science advisor, Sir David King, reassured journalists that the natural disaster that precipitated the failure had been 'an extremely unlikely event' (Harvey 2011). In doing so, he exemplified the many early accounts of Fukushima that emphasised the improbable nature of the earthquake and tsunami that precipitated it. A range of professional bodies made analogous claims around this time, with journalists following their lead. This lamentation, by a consultant writing in the *New American,* is illustrative of the general tone:

> ... the Fukushima 'disaster' will become the rallying cry against nuclear power. Few will remember that the plant stayed generally intact despite being hit by an earthquake with more than six times the energy the plant was designed to withstand, plus a tsunami estimated at 49 feet that swept away backup generators 33 feet above sea level (Hiserodt 2011).

The explicit or implicit argument in all such accounts is that the Fukushima's proximate causes are so rare as to be almost irrelevant to nuclear plants in the future. Nuclear power is safe, they suggest, except against the specific kind of natural disaster that struck Japan, which is both a specifically Japanese problem, and one that is unlikely to re-occur, anywhere, in any realistic timeframe.

The logic of this is tenuous on various levels. The 'improbability' of the natural disaster is disputable, for one, as there were good reasons to believe that neither the earthquake nor the tsunami should have been surprising. The area was well known to be seismically active after all, and the quake, when it came, was only the fourth largest of the last century.[4] The Japanese nuclear industry had even confronted its seismic under-preparedness four years earlier, on 16 July 2007, when an earthquake of unanticipated magnitude damaged the Kashiwazaki-Kariwa nuclear plant. This had led several analysts to highlight Fukushima's vulnerability to earthquakes, but officials had said much the same then as they now said in relation to Fukushima (Perrow 2011: 47; Tabuchi 2012). The tsunami was not without precedent either. Geologists had long known that a similar event had occurred in the same area in July 869. This was a long time ago, certainly, but the data indicated a thousand-year return cycle (Farber 2012).[5] Haruki Madarame, the head of Japan's Nuclear Safety Commission, has criticised Fukushima's operator, TEPCO, for denying that it could have anticipated the flood.

The claim that Japan is 'uniquely vulnerable' to such hazards is similarly disputable. In July 2011, for instance, the *Wall Street Journal* reported on private NRC emails showing that the industry and its regulators had evidence that many US reactors were at risk from earthquakes that had not been anticipated in their design. It noted that the regulator had taken very little or no action to accommodate this new understanding (Andrews & Folger 2012: 29; Smith & Maremont 2011). As if to illustrate their concern, on 23 August 2011, less than six months after Fukushima, North Anna nuclear plant in Mineral, Virginia, was rocked by an earthquake that exceeded its design-basis predictions (Andrews & Folger 2012; Frommer 2011).

There is, moreover, a larger and more fundamental reason to doubt the 'unique events or vulnerabilities' narrative, which lies in recognising its implicit assertion that nuclear plants are safe against everything except the events that struck Japan. It is important to understand that those who assert that nuclear power is safe because the 2011 earthquake and tsunami will not re-occur are, essentially, saying that although the industry failed to anticipate those events, it *has* anticipated all the others. Yet even a moment's reflection reveals that this is highly unlikely. It supposes that experts can be sure they have comprehensively predicted all the challenges that nuclear plants will face in its lifetime (or, in engineering parlance: that the 'design basis' of every nuclear plant is correct), even though a significant number of technological disasters, including Fukushima, have resulted, at least in part, from conditions that engineers failed to even consider (see

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[4] The others were not in Japan, as analysts have been quick to point out. But given Japan's tectonic position there was no a priori reason to imagine that it would not be next. There is little evidence that, among the seismically vulnerable areas of the world, some are more prone to 9.0+ earthquakes than others.

[5] Several reports, meanwhile, have suggested that the earthquake alone might have precipitated the meltdown, even without the tsunami – a view supported by a range of evidence, from worker testimony, to radiation alarms that sounded before the tsunami (McNeil & Adelstein 2011; Okada et al. 2011).

Downner 2011b). As Sagan (1993: 12) points out: 'things that have never happened before, happen all the time'. The terrorist attacks of 9/11 are perhaps the most iconic illustration of this dilemma but there are many others. Perrow (2007) painstakingly explores a landscape of potential disaster scenarios that authorities do not formally recognise, but it is highly unlikely that he has considered them all. More are hypothesised all the time. For instance, researchers have recently speculated about the effects of massive solar storms, which, in pre-nuclear times, have caused electrical systems over North America and Europe to fail for weeks at a time (Ladkin 2012; Stein 2012).

2. *The claim that the accident resulted from human failings that are both unrepresentative and/or correctable*

A second rationale that accounts of Fukushima invoke to establish that accidents will not re-occur focuses on the people who operated or regulated the plant, and the institutional culture in which they worked. Observers who opt to view the accident through this lens invariably construe it as the result of human failings – either error, malfeasance or both.

The majority of such narratives relate the failings they identify directly to Fukushima's specific regulatory or operational context, thereby portraying it as a 'Japanese' rather than a 'nuclear' accident (Greene 2012; Gusterson 2011). Many, for instance, stress distinctions between US and Japanese regulators; often pointing out that the Japanese nuclear regulator (NISA) was subordinate to the Ministry of Trade and Industry, and arguing that this created a conflict of interest between NISA's responsibilities for safety and the Ministry's responsibility to promote nuclear energy (eg: Adelstein & McNeill 2011; Ichida et al. 2011; Marvel & May 2011; Monbiot 2011).[6] Other accounts point to TEPCO, the operator of the plant, and find it to be distinctively 'negligent' (e.g. Acton & Hibbs 2012b; ANS 2012). A common assertion in vein, for instance, is that it concealed a series of regulatory breaches over the years, including data about cracks in critical circulation pipes that were implicated in the catastrophe (e.g. Adelstein & McNeill 2011). There are two subtexts to these accounts. Firstly, that such an accident will not happen here (wherever 'here' may be) because 'our' regulators and operators 'follow the rules'. And secondly, that these failings can be amended so that similar accidents will not re-occur, even in Japan.

[6] They point, for instance, to the fact that NISA had recently been criticised by the International Atomic Energy Agency (IAEA) for a lack of independence, in a report occasioned by earthquake damage at another plant (IAEA 2007). Or to evidence that NISA declined to implement new IAEA standards out of fear that they would undermine public trust in the nuclear industry (Kubota 2012).

Where accounts of the human failings around Fukushima do portray those failings as being characteristic of the industry beyond Japan, the majority still construe those failings as eradicable. In March 2012, for instance, the Carnegie Endowment for International Peace issued a report that highlighted a series of organisational fallings associated with Fukushima, not all of which they considered to be meaningfully Japanese (Acton & Hibbs 2012a). Nevertheless, the report – entitled 'Why Fukushima was preventable' – argued that such failings could be resolved. 'In the final analysis,' it concluded, 'the Fukushima accident does not reveal a previously unknown fatal flaw associated with nuclear power' (ibid: 2). The same message echoes in the many post-Fukushima actions and pronouncements of nuclear authorities around the world promising managerial reviews and reforms, such as the IAEA's hastily announced 'five-point plan' to strengthen reactor oversight (Amano 2011).

As with the previous narratives about exogenous hazards, however, the logic of these 'human failure' arguments is also tenuous. Despite the editorial consternation that revelations about Japanese malfeasance and mistakes have inspired, for instance, there are good reasons to believe that neither were exceptional. It would be difficult to deny that Japan had a first-class reputation for managing complex engineering infrastructures, for instance[7] Reports of Japanese management failings must be considered in relation to the fact that reports of regulatory shortcomings, operator error, and corporate malfeasance abound in every state with nuclear power and a free press (see e.g. Donn 2011; Perin 2005; Perrow 2007). There exists a long tradition of accident investigations finding variations in national safety practices that are later rejected on further scrutiny (Perrow 1999: 358; Silbey 2009: 349).[8]

Arguments suggesting that 'human' problems are potentially solvable are similarly difficult to sustain, for there are compelling reasons to believe that operational errors are an inherent property of all complex socio-technical systems. Close accounts of even routine technological work, for instance, routinely find it to be necessarily and unavoidably 'messier' in practice than it appears on paper (e.g Downer 2007; Langewiesche 1998; Perin 2005; Perrow 1983; Wynne 1988).[9] These studies undermine

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[7] As the title of one op-ed in the *Washington Post* puts it: 'If the competent and technologically brilliant Japanese can't build a completely safe reactor, who can?' (Applebaum 2011).

[8] When Western experts blamed Chernobyl on the practices of Soviet nuclear industry (e.g. Socolow 2011), for example, they unconsciously echoed Soviet narratives highlighting the inferiority of Western safety cultures to argue that an accident like Three Mile Island could never happen in the USSR (Schmid 2011a).

[9] Thus both human error and non-compliance are ambiguous concepts. As Wynne (1988: 154) observes: '... the illegitimate extension of technological rules and practices into the unsafe or irresponsible is never clearly definable, though there is ex-post pressure to do so'. The culturally satisfying nature of 'malfeasance explanations' should, by itself, be cause for circumspection.

the notion of 'perfect rule compliance' by showing that even the most expansive stipulations sometimes require interpretation and do not relieve workers of having to make decisions in uncertain conditions (Mackenzie 2003; Schmid 2011a).

In this context we should further recognise that accounts that show Fukushima, *specifically*, was preventable are not evidence that nuclear accidents, *in general*, are preventable. To argue from analogy: it is true to say that any specific crime might have been avoided (otherwise it wouldn't be a crime), but we would never deduce from this that crime, the phenomenon, is eradicable. Human failure will always be present in the nuclear sphere at some level, as it is in all complex socio-technical systems. And, relative to the reliability demanded of nuclear plants, it is safe to assume that this level will always be too high or, at least, that our certainty regarding it will be too low. While human failures and malfeasance are undoubtedly worth exploring, understanding and combating, therefore, we should avoid the conclusion that they can be 'solved'.

3. *The claim that the accident resulted from the design of the plant itself, which is unrepresentative and/or correctable*

Parallel to narratives about Fukushima's circumstances and operation, outlined above, are narratives that emphasise the plant itself. These limit the relevance of accident to the wider nuclear industry by arguing that the design of its reactor (a GE Mark-1) was unrepresentative of most other reactors, while simultaneously promising that any reactors that were similar enough to be dangerous could be rendered safe by 'correcting' their design.

Accounts in this vein frequently highlight the plant's age, pointing out that reactor designs have changed over time, presumably becoming safer. A UK civil servant exemplified this narrative, and the strategic decision to foreground it, in an internal email (later printed in the *Guardian* [2011]), in which he asserted that 'We [The Department of Business, Innovation and Skills] need to … show that events in Japan, whilst looking dramatic, are all part of the safety processes of this 1960's reactor.'[10]

Stressing the age of the reactor in this way became a mainstay of Fukushima discourse in the disaster's immediate aftermath. *Guardian* columnist George Monbiot (2011b), for instance, described Fukushima as 'a crappy old plant with inadequate safety features' and concluded that its failure should not speak to the integrity of later designs, like that of the neighboring plant, Fukushima 'Daini', which did not fail in the tsunami. 'Using a

[10] See: <http://www.guardian.co.uk/environment/interactive/2011/jun/30/email-nuclear-uk-government-fukushima?intcmp=239>

plant built 40 years ago to argue against 21st-century power stations,' he wrote, 'is like using the Hindenburg disaster to contend that modern air travel is unsafe' (Monbiot 2011).

Other accounts highlighted the reactor's design but focused on more generalisable failings, such as the 'insufficient defense-in-depth provisions for tsunami hazards' (IAEA 2011a: 13), which could not be construed as indigenous only to the Mark-1 reactors or their generation. These failings could be corrected, however, or such was the implication. The American Nuclear Society (ANS 2011) set the tone, soon after the accident, when it reassured the world that: 'the nuclear power industry will learn from this event, and redesign our facilities as needed to make them safer in the future'. Almost every official body with responsibility for nuclear power followed in their wake. The IAEA, for instance, orchestrated a series of rolling investigations, which eventually cumulated in the announcement of its 'Action Plan on Nuclear Safety' and a succession of subsequent meetings where representatives of different technical groups could pool their analyses and make technical recommendations (IAEA 2011a; 2011b; 2012).[11]

Again, however, there is ample cause for scepticism.

Firstly, there are many reasons to doubt that Fukushima's specific design or generation made it exceptionally vulnerable. As noted above, for instance, many of the specific design failings identified after the disaster – such as the inadequate water protection around reserve power supplies – were broadly applicable across reactor designs. And even if the reactor design or its generation were exceptional in some ways, that exceptionalism is decidedly limited. There are currently thirty-two Mark-1 reactors in operation around the world (Marvel & May 2011: 3), and many others of a similar age and generation, especially in the US, where every reactor currently in operation was commissioned before the Three Mile Island accident in 1979.

Secondly, there is little reason to believe that most existing plants could be retrofitted to meet all Fukushima's lessons. Significantly raising the seismic resilience of a nuclear plant, for instance, implies such extensive design changes that it might be more practical to decommission the entire structure and rebuild from scratch. This perhaps explains why progress has been halting on the technical recommendations.[12] It might be true that

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[11] The groups invariably conclude that 'many lessons remain to be learned' and recommend further study and future meetings.

[12] In March 2012, the NRC did announce some new standards pertaining to power outages and fuel pools – issuing three 'immediately effective' orders requiring operators to implement some of the more urgent recommendations. The required modifications were relatively modest, however, and 'immediately' in this instance meant 'by December 31st 2016' (DiSavino 2012; Tracy 2012; Wingfield 2012;). Meanwhile, the approvals for four new reactors the NRC granted around this time contained no

different, or more modern reactors are safer, therefore, but these are not the reactors we have.

Finally, and most fundamentally, there are many a priori reasons to doubt that any reactor design could be as safe as risk analyses suggest. Observers of complex systems have outlined strong arguments for why critical technologies are inevitably prone to some degree of failure, whatever their design. The most prominent such argument is Normal Accident Theory (NAT) (Perrow 1999), with its simple but profound probabilistic insight that accidents caused by very improbable confluences of events (that no risk calculation could ever anticipate) are 'normal' in systems where there are many opportunities for them to occur.[13] From this perspective, the 'we-found-the-flaw-and-fixed-it' argument is implausible because it offers no way of knowing how many 'fateful coincidences' the future might hold. 'Lesson 1' of the IAEA's preliminary report on Fukushima is that the '... design of nuclear plants should include sufficient protection against infrequent and complex combinations of external events' (IAEA 2011a: 16). NAT explains why an irreducible number of these 'complex combinations' must be forever beyond the reach of formal analysis and managerial control.[14]

A different way of demonstrating much the same conclusion is to point to the fundamental epistemological ambiguity of technological knowledge, and to how the significance of this ambiguity is magnified in complex, safety-critical systems due to the very high levels of certainty these systems require (Downer 2007, 2011a, 2011b).[15] Viewed from this perspective, it becomes apparent that complex systems are likely to be prone to failures arising from erroneous beliefs that are impossible to predict in advance, which I have elsewhere called 'Epistemic Accidents' (Downer 2011b). This is essentially to say that the 'we-found-the-flaw-and-fixed-it' argument cannot guarantee perfect safety because it offers no way of knowing how many new 'lessons' the future might hold. Just as it is impossible for engineers and regulators to know for certain that they have anticipated every external event a nuclear plant might face, so it is impossible for them know that their understanding of the system itself is completely accurate. Increased safety margins, redundancy, and defense-in-depth undoubtedly might improve reactor safety, but no amount of engineering wizardry can offer perfect safety, or even

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binding commitment to implement the wider lessons it derived from Fukushima (Abernethy 2012; Wingfield & Johnsson 2012). In each case, the increasingly marginalised NRC chairman, Gregory Jaczko, cast a lone dissenting vote. He was also the only committee member to object to the 2016 timeline.

[13] See also: Sagan (2004); Downer (2011b).

[14] For more on this, see Downer (2011b).

[15] Judgements become more significant in this context because they have to be absolutely correct. There is no room for error-bars in such calculations. It makes little sense to say that we are 99 per cent certain a reactor will not explode, but only 50 per cent sure that this number is correct.

safety that is ‘knowably’ of the level that nuclear plants require. As Gusterson (2011), puts it: ‘... the perfectly safe reactor is always just around the corner’.[16]

The reliability myth

This is all to say, in essence, that it is misleading to assert that an accident of Fukushima’s scale will not re-occur. For there are credible reasons to believe that the reliability required of reactors is not calculable, and there are credible reasons to believe that the actual reliability of reactors is much lower than is officially calculated. These limitations are clearly evinced by the actual historical failure rate of nuclear reactors. Even the most rudimentary calculations show that civil nuclear accidents have occurred far more frequently than official reliability assessments have predicted. The exact numbers vary, depending on how one classifies ‘an accident’ (whether Fukushima counts as one meltdown or three, for example), but Ramana (2011) puts the historical rate of serious meltdowns at 1 in every 3,000 reactor years, while Taebi et al. (2012: 203fn) put it at somewhere between 1 in every 1,300 to 3,600 reactor years. Either way, the implied reliability is orders-of-magnitude lower than assessments claim.[17]

Attempts to dismiss this historical record by pointing to specific ways in which accidents are unrepresentative often make useful observations, and they all speak to a meaningful question about the appropriate level of aggregation and the significance of small numbers in energy data (see Felder 2009: 5745; Fritzsche 1989: 567; Holdren et al. 1980: 265). For all this, however, yet they miss a wider point — that every argument that an accident is not representative is, in effect, a testament to the fact that the formal calculations on which experts base safety assurances consistently fail to account for variables, such as human behavior, that significantly affect the probability of reactor failures.

[16] Nuclear authorities sometimes concede this. After the IAEA’s 2012 recommendations to pool insights from the disaster, for instance, the meeting’s chairman, Richard Meserve, summarised: ‘In the nuclear business you can never say, “the task is done”’ (IAEA 2012). Instead they promise improvement. ‘The Three Mile Island and Chernobyl accidents brought about an overall strengthening of the safety system,’ Meserve continued, ‘it is already apparent that the Fukushima accident will have a similar effect’ (IAEA 2012). The real question, however, is when will the safety be strong enough? As it wasn’t after Three Mile Island or Chernobyl, why should Fukushima be any different?

[17] In a recent declaration to a UK regulator, for instance, Areva, a prominent French nuclear manufacturer, invoked probabilistic calculations to assert that the likelihood of a ‘core damage incident’ in its new ‘EPR’ reactor were of the order of one incident, per reactor, every 1.6 million years (Ramana 2011).

Two: the accident was tolerable

The second basic narrative through which accounts of Fukushima have kept the accident from undermining the wider nuclear industry rests on the claim that its effects were tolerable. That even though the costs of nuclear accidents might look high, when amortised over time they are acceptable relative to the alternatives.

The 'accidents are tolerable' argument is invariably framed in relation to the health effects of nuclear accidents. 'As far as we know, not one person has died from radiation,' Sir David King told a press conference in relation to Fukushima (Harvey 2011), neatly expressing a sentiment that would be echoed in editorials around the world in the aftermath of the accident. 'Atomic energy has just been subjected to one of the harshest of possible tests, and the impact on people and the planet has been small,' concluded Monbiot (2011b) in one characteristic column. 'History suggests that nuclear power rarely kills and causes little illness,' the *Washington Post* reassured its readers (Brown 2011).[18] 'Fukushima's Refugees Are Victims Of Irrational Fear, Not Radiation,' declared the title of an article in *Forbes* (Conca 2012).

In its more sophisticated forms, this argument draws on comparisons with other energy alternatives. A 2004 study by the American Lung Association argues that coal-fired power plants shorten the lives of 24,000 people every year (MSNBC 2004). Chernobyl, widely considered to be the most poisonous nuclear disaster to date, is routinely thought to be responsible for around 4,000 past or future deaths (IAEA 2005: 15). Even if the effects of Fukushima are comparable (which the majority of experts insist they are not), then, by these statistics, the human costs of nuclear energy seem almost negligible, even when accounting for its periodic failures.

Such numbers are highly contestable, however. Partly because there are many more coal than nuclear plants (a fairer comparison might consider deaths-per-kilowatt-hour). But mostly because calculations of the health effects of nuclear accidents are fundamentally ambiguous. Chronic radiological harm can manifest in a wide range of maladies, none of which are clearly distinguishable as being radiologically induced – they have to be distinguished statistically – and all of which have a long latency, sometimes of decades or even generations (see e.g. Bennett et al. 2006). So it is that mortality estimates about nuclear accidents inevitably depend on an array of complex assumptions and judgments that allow for radically divergent – but equally 'scientific' – interpretations of the same data. Some claims are more compelling than others, of course, but 'truth' in this realm does not 'shine by its own lights' as we invariably suppose it ought (Dupuy 2007; Johnson 2011).

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[18] See also e.g. McCulloch (2011); Harvey (2011).

Take, for example, the various studies of Chernobyl's mortality, from which estimates of Fukushima's are derived. The models underlying these studies are themselves derived from data from Hiroshima and Nagasaki survivors, the accuracy and relevance of which have been widely criticised (see e.g. Greene 2012), and they require the modeller to make a range of choices with no obviously correct answer. Modellers must select between competing theories of how radiation affects the human body, for instance; between widely varying judgments about the amount of radioactive material the accident released; and much more. Such choices are closely interlinked and mutually dependent. Estimates of the composition and quantities of the isotopes released in the accident, for example, will affect models of their distribution, which, in conjunction with theories of how radiation affects the human body, will affect conclusions about the specific populations at risk. This, in turn, will affect whether a broad spike in mortality should be interpreted as evidence of radiological harm or as evidence that many seemingly radiation-related deaths are actually symptomatic of something else. And so on ad infinitum: a dynamic tapestry of theory and justification, where subtle judgements reverberate throughout the system. The net result is that quiet judgements concerning the underlying assumptions of an assessment – usually made in the very earliest stages of a study and all but invisible to most observers – have dramatic affects on its findings (Barisonek 2011; Greene 2012; Perrow 2013).

The effects of this are visible in the widely divergent assertions made about Chernobyl's death toll. The 'orthodox' mortality figure cited above – no more than 4,000 deaths – comes from the 2005 IAEA-led 'Chernobyl Forum'[19] report (IAEA 2005: 15).[20] This number is endorsed and cited by most international nuclear authorities, yet it stands in stark contrast to the findings of similar investigations. Two reports published the following year, for example, offer much higher figures: one estimating 30,000 to 60,000 cancer deaths (Fairlie & Sumner 2006); the other 200,000 or more (Greenpeace 2006: 10). In 2009, meanwhile, the New York Academy of Sciences published an extremely substantive Russian report that raised the toll even further, concluding that in the years up to 2004, Chernobyl caused around 985,000 premature cancer deaths worldwide (Yablokov 2009). Between these two figures – 4,000 and 985,000 – lie a host of other expert estimations of Chernobyl's mortality, many of them seemingly rigorous and authoritative.[21]

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[19] The Chernobyl Forum consisted of a group of specialists, including the representatives of the IAEA, the UN Scientific Committee on the Influence of Atomic Radiation (UNSCAR), WHO and other UN programmes, as well as the World Bank and various state organisations of Belarus, Russia and Ukraine.
[20] Or rather, the heavily bowdlerised press release from the IAEA that accompanied its executive summary. The actual health section of the report alludes to much higher numbers (Bennett et al. 2006).
[21] The Greenpeace report (2006: 24) tabulates some of the varying estimates and correlates them to differing methodologies.

Different sides in this contest of numbers routinely assume their rivals are actively attempting to mislead,[22] and there is certainly some evidence for this (see e.g. Perrow 2013).[23] It is perhaps more useful, however, to say they are each discriminating about the realities to which they adhere. In this realm there are no entirely objective facts, and with so many judgements it is easy to imagine how even small, almost invisible biases, might shape the findings of seemingly objective hazard calculations. Indeed, many of the judgements that separate divergent nuclear hazard calculations are inherently political, with the result that there can be no such thing as an entirely neutral account of nuclear harm. Researchers must decide whether a 'stillbirth' counts as a 'fatality,' for instance. They must decide whether an assessment should emphasise deaths exclusively, or if it should encompass all the injuries, illnesses, deformities and disabilities that have been linked to radiation. They must decide whether a life 'shortened' constitutes a life 'lost'. There are no correct answers to such questions. More data will not resolve them. Researchers simply have to make choices.

The net effect is that the hazards of any nuclear disaster can only be glimpsed obliquely through a distorted lens. So much ambiguity and judgement is buried in even the most rigorous calculations of Fukushima's health impacts that no study can be definitive. All that remains are impressions and, for the critical observer, a vertiginous sense of possibility. The only thing to be said for sure is that declarative assurances of Fukushima's low death toll are misleading in their surety.

Given the intense fact-figure crossfire around radiological mortality, it is unhelpful to view Fukushima purely through the lens of health. In fact, the emphasis on mortality might itself be considered a way of minimising Fukushima, considering that there are other – far less ambiguous – lenses through which to view the disaster's consequences. Fukushima's health effects are contested enough that they can be interpreted in ways

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[22] A wide range of critics argue that most official accounts are authored by industry apologists who 'launder' nuclear catastrophes by dicing evidence of their human fallout into an anodyne melee of claims and counter claims (e.g. Barisonek 2011; Dupuy 2007; Fairlie & Sumner 2006; Greene 2012; Johnston 2011; Perrow 2013). When John Gofman, a former University of California Berkeley Professor of Medical Physics, wrote that the Department of Energy was 'conducting a Josef Goebels propaganda war' by advocating a conservative model of radiation damage (Gofman 1994), for instance, his charge more remarkable for its candor than its substance.

[23] There can be little doubt that in the past the US government has intentionally clouded the science of radiation hazards to assuage public concerns. The 1995 US Advisory Committee on Human Radiation Experiments, for instance, concluded that Cold War radiation research was heavily sanitised for political ends. A former AEC (NRC) commissioner testified in the early 1990s that: 'One result of the regulators' professional identification with the owners and operators of the plants in the battles over nuclear energy was a tendency to try to control information to disadvantage the anti-nuclear side' (Madrigal 2011: 230).

that make the accident look tolerable, but it is much more challenging to make a case that it was tolerable in other terms.

Take, for example, the disaster's economic impact. The intense focus on the health and safety effects of Fukushima has all but eclipsed its financial consequences, yet the latter are arguably more significant and are certainly less ambiguous (e.g. Cooper 2012: iv). Nuclear accidents incur a vast spectrum of costs. There are direct costs relating to the need to seal off the reactor; study, monitor and mitigate its environmental fallout; resettle, compensate and treat the people in danger; and so forth.[24] Then there is an array of indirect costs that arise from externalities, such as the loss of assets like farmland and industrial facilities;[25] the loss of energy from the plant and those around it; the impact of the accident on tourism; and so forth.

The exact economic impact of a nuclear accident is almost as difficult to estimate as its mortality, and projections differ for the same fundamental reasons. They do not differ to the same degree, however, and in contrast to Fukushima's mortality there is little contention that its financial costs will be enormous. By November of 2013, the Japanese government had already allocated over 8 trillion yen (roughly $80 billion or £47 billion) to Fukushima's clean-up alone – a figure that excluded the cost of decommissioning the six reactors, a process expected to take decades and cost tens of billions of dollars (Takemoto 2013). Independent experts have estimated the clean-up cost to be in the region of $500 billion (Gunderson & Caldicott 2012). These estimates, moreover, exclude most of the indirect costs outlined above, such as the disaster's costs to food and agriculture industries, which the Japanese Ministry of Agriculture, Forestries and Fisheries (MAFF) has estimated to be 2,384.1 billion yen (roughly $24 billion) (Bachev & Ito 2013: 1).

Of these competing estimates, the higher numbers seem more plausible. The notoriously conservative report of the Chernobyl Forum estimated that the cost of that accident had already mounted to 'hundreds of billions of dollars' after just 20 years (IAEA 2005: 32), and it seems unlikely that Fukushima's three meltdowns could cost less (see Boardman 2014). Even if we assume that Chernobyl was more hazardous than Fukushima (a common conviction that is incrementally becoming more tenuous), then it remains true that the same report projected the 30-year costs cost to Belarus alone to be US$235

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[24] Over a quarter of a century after Chernobyl, the accident still haunts Western Europe, where government scientists in several countries continue to monitor certain meats, and keep some from entering the food chain.

[25] The evacuation zone around Fukushima – an area of around 966 sq km, much of which will be uninhabitable for generations – covers 3 per cent of Japan, a densely populated and mountainous country where only 20 per cent of the land is habitable in the first place (eg: CEPR 2011; Vidal 2011).

billion (IAEA 2005: 32), and that Belarus's lost opportunities, compensation payments and clean-up expenditures are unlikely to rival Japan's.[26]

To put these figures into perspective, consider that nuclear utilities in the US are required to create an industry-wide insurance pool of only about $12 billion for accident relief, and are protected against further losses by the Price-Anderson Act, by which the US Congress has socialised the costs of any nuclear disaster. The nuclear industry needs such extraordinary government protection in the US, as it does in all countries, because – for all the authoritative, blue-ribbon risk assessments demonstrating its safety – the reactor business, almost uniquely, is unable to secure private insurance (Cooper 2012; Shrader-Frechette 2011).

The industry's unique dependence on limited liabilities reflects the fact that no economic justification for atomic power could concede the evitability of major accidents like Fukushima and remain viable or competitive. As Mark Cooper, the author of a 2012 report on the economics of nuclear disaster has put it: 'If the owners and operators of nuclear reactors had to face the full liability of a Fukushima-style nuclear accident or go head-to-head with alternatives in a truly competitive marketplace, unfettered by subsidies, no one would have built a nuclear reactor in the past, no one would build one today, and anyone who owns a reactor would exit the nuclear business as quickly as possible' (Koebler 2012).

The spectre of possibility

Experts will no doubt be parsing the consequences of Fukushima for a generation if not more. In the final analysis, however, it is arguable that its most unambiguous lesson regarding the costs of nuclear accidents will concern not what did happen but what could have happened.

The opening months of 2012 saw the release of an authoritative report, undertaken on behalf of the diet of Japan by the Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident (NAIIC: 2012). The report, which offered new insights into the highest level deliberations around the meltdown, unequivocally concluded that the accident could have been considerably worse than it was. To quote its executive summary:

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[26] Considering, for instance, Japan's much higher cost of living, its indisputable loss of six reactors and decision to at least shutter the remainder of its nuclear plants, and many other factors. The Chernobyl reactor did not even belong to Belarus, it is in what is now the Ukraine.

> The Commission discovered that, in reality, an even worse situation could have developed at Units 2 and 3, and the situations at Unit 5 and 6 could have easily worsened. […] Damage to the spent fuel of Unit 4 could have occurred, with greater affect to the wider surrounding environment. There was a distinct potential at the time for this disastrous accident to result in an even more frightening scenario (NAIIC 2012: 30).

Although the report was initially available only in Japanese, its release was accompanied by a flood of unnerving, high-level testimony. 'We barely avoided the worst-case scenario, though the public didn't know it at the time,' the Chairman of the report told reporters. 'It was extreme luck that Japan managed to avoid experiencing the most disastrous day,' said another prominent member of the inquiry (Lean 2012).

Just how disastrous that day might have been can be inferred from the singularly startling revelation that the Japanese Cabinet had concluded it might have to evacuate Tokyo City (e.g. Fackler 2012). 'I had this demonic scenario in my head [where] Tokyo will be finished,' Yukio Edano, the chief cabinet secretary, told investigators (Goodspeed 2012; Lean 2012). Kan Naoto, the Prime Minister at the time of the crisis, went so far as to tell the *Wall Street Journal* that his country's 'existence as a sovereign nation was at stake' (Quintana 2012).

At the time, many commentators disputed the credibility of the 'Tokyo scenario'; perhaps suspecting a hitherto under-recognised proclivity for hyperbole in the highest echelons of Japanese society. Most argued that it was incommensurable with the data about the radioactive releases from the failed reactors (e.g. Worstall 2012). And it remains common to hear that US NRC analyses performed at the time of the accident showed no risk to Tokyo city. Such disclaimers are misleading, however. The NRC's reassurances are true in the most literal sense that its models showed no threat to Tokyo, but those models were performed using a system called RASCAL[27] that was incapable of simulating threats beyond a 50-mile radius, meaning that it could not have shown a threat to Tokyo under any circumstances.[28] Public speculation about the radioactive potential of the failed reactors, meanwhile, universally missed that the key to understanding the threat to Japan's capital lay not in the reactors per se, but in less reported fears about a spent fuel pool in one of the ruined reactor buildings.

Unit 4's spent fuel pool – an unshielded container of water poised about100 feet above the reactor – contained 1,535 fuel assemblies, each consisting of between 50 and 70 individual fuel rods, some of which were unspent rods waiting to be inserted into the

[27] The **R**adiological **A**ssessment **S**ystem for **C**onsequence **A**na**L**ysis
[28] Anonymous NRC interlocutor.

reactor (Dvorak 2012b; Matsumura 2012). For these highly radioactive assemblies to remain stable it was vital that they be constantly cooled by circulating water, without which they would quickly heat up and begin to burn uncontrollably, releasing a vast could of radio-nucleotides into the atmosphere. This would have been nothing short of catastrophic. The pool contained about 10 times the volume of Cesium-137 as the Chernobyl reactor. It is very probable, moreover, that such a fire would have jeopardised another, even larger, pool nearby. It stored fuel from all six reactors – 6,375 fuel assemblies, roughly 85 times the amount of radioactive Caesium released by the Chernobyl accident (Matsumura 2012).

An uncontrollable spent-fuel fire would undoubtedly have jeopardised Tokyo, and it is now clear that this is precisely what many expert observers, both in Japan and abroad, had feared. One need only look at the shattered state of the Unit 4 reactor building after the accident to understand why the pool was considered to be at risk (Dvorak 2012a). Indeed, there is substantial evidence that the pool was leaking to a degree that led to a nascent zirconium fire, which was brought under control before it got out of hand. (Not least the fact that the building exploded, despite there being no fuel in the reactor core.)[29]

Even putting environmental and health implications of such an event aside, the fact that a single technological disaster could realistically have felled Japan's capital city should weigh inexorably on the scales of any political calculation about nuclear power. Tokyo, arguably the most populous metropolitan area in the world, is home to over 35 million people: twice the population of New York, three times that of London. Together with those cities, it is widely considered one of the three 'command centres' of the global economy, with a GDP estimated at US$1,479 trillion in 2008 – the highest of any city on the planet. Should it have been lost in the fashion of Pripyat or Tomioka, the social, cultural and economic fallout would have been profound. The economic consequences alone would have represented a financial *Götterdämmerung.* The direct costs of losing Tokyo and repopulating its residents, combined with the lost revenues and opportunity costs associated with doing so, are difficult to estimate. There can be no doubt, however, that they would have been a profound shock to the global financial markets. At the very least, they would have jeopardised Japan's ability to service its national debt. Critics have dismissed the Prime Minister's statement about his nation's

[29] The US decision not to order an evacuation beyond 50 miles (quickly echoed by the UK), should be understood as a political calculation aimed to appease a Japanese government that was worried that a US evacuation would have led to uncontrollable panic in their capital (and which, prior to the accident, had been increasingly concerned about US military bases on its soil). The Germans advised their citizens to evacuate the capital, no doubt at some diplomatic cost. So had the French, the Russians and the Chinese – all countries with heavy nuclear commitments that an evacuation might seem to undermine.

sovereignty hanging in the balance as rhetorical embroidery, but in this context his assessment seems entirely sober. For all the manifest shortcomings of other energy options, it is difficult to imagine that any offer risks on such a scale.

The wider picture

So it is that the narratives of Fukushima shape its socio-political significance by challenging its relevance and downplaying its consequences. It would be wrong to deny, moreover, that these narratives have a seductive logic and a degree of insight. The specific circumstances of all nuclear accidents do differ in ways that limit their broader relevance (at least in some respects). Technologies and practices undoubtedly do often improve with the lessons of experience (although this is by no means inevitable). The ambiguities of nuclear fallout mean that its health risks could theoretically be minimal. All of these claims are potentially valid, even if they are not always very compelling.

At the same time, however, an institutional proclivity to frame the disaster in these ways systematically occludes much more significant insights. These include:

- That the probability of nuclear accidents is not a variable that experts can objectively and definitively 'calculate';
- That formal reliability calculations, by necessity, make unrealistic assumptions that can only inflate their estimates, (for instance about rule-compliance by operators and regulators);
- That every large socio-technical system and hence every technological disaster is unique in some respects, and there is a fundamental imbalance in treating those that fail as exceptional relative to those that do not;
- That there are compelling reasons to believe that some accidents will always be unforeseeable and unavoidable in systems like nuclear plants, regardless of their design, management and oversight;

All of the above undermine assertions that nuclear accidents 'will not reoccur'. And further insights:

- That the ambiguities around nuclear health hazards mean that those hazards could credibly be orders-of-magnitude higher than the estimates promulgated by nuclear advocates like the IAEA and then invoked in formal risk analyses;
- That the economic consequences of nuclear accidents are much less contestable than their health costs, and are high enough that no cost justification of nuclear energy could concede even the possibility of a meltdown and remain viable;
- That Fukushima was not a 'worst case scenario'; and was almost, and still might be, vastly more costly, hazardous and consequential than it currently appears.

All of which undermine assertions that nuclear accidents are 'tolerable'.

Neither group of insights could be described as obscure or entirely unrecognised. They are routinely echoed by anti-nuclear groups, for instance, and are structurally implicit in the fact that nuclear operators remain unable to buy insurance. Yet the fact that they are pervasively excluded from formal US and UK nuclear discourse and decision making is more than evinced by the institutional realities of nuclear energy in these countries. It can be seen, for example, in the absence of accidents (or even the possibility thereof) in cost-benefit analyses; in extremely modest nuclear emergency planning and resilience measures; in the 'clustering' of many reactors in single sites; and much else besides. Indeed, it is arguably evident in the continued investment nuclear energy.

The sociology of denial

It is tempting to end the discussion here, having noted these conspicuous shortcomings in public nuclear discourse. Yet such absences intuitively suggest a further, more sociological, insight that is deserving of further examination – that powerful institutional interests are able to shape public discourse around nuclear energy. There are at least two ways of interpreting this sociologically.

Perhaps the most tempting and intuitive lens through which to understand the claim that institutional interests shape nuclear discourse, is through the burgeoning sociological literature sometimes referred to as 'agnotology' (Proctor & Schiebinger 2008), or 'anti-epistemology' (McGoey 2012). This work – which, for simplicity's sake, I will collectively refer to as agnotology – explores how established organisational networks intentionally pursue their interests by cultivating doubt, ignorance or false knowledge (e.g. McGoey 2012; Oreskes & Conway 2010; Proctor & Schiebinger 2008). Oreskes & Conway (2010), for instance, compellingly explain how the tobacco and oil industries actively managed their liabilities in regard to lung cancer and environmental hazards by manipulating the institutional workings of science and its relationship to the media.

Underlying the agnotology literature is a claim about agency. It recognises that there are epistemological 'malefactors': self-aware, arguably cynical, operators who actively work to undermine the credibility of knowledge-claims that they themselves recognise to be true. Tobacco companies, for instance, which publicly challenged a link between smoking and lung cancer long after they accepted it in private (Oreskes & Conway 2010). This is a valuable insight in a society that must increasingly makes decisions on the basis of expert advice, and nuclear advocates almost certainly fit this pattern to some degree. When highly placed NRC officials deny that Fukushima endangered Tokyo by referencing models they know cannot project beyond 50 miles, for example, it is undeniably an elision, even if they believe it to be justified in relation to a broader truth.

Insofar as the viability of the agnotology literature rests on the there always being a credible ‘dissembler’ and an established ‘truth’ for them to obscure, however, then it is almost certainly incomplete when it comes to explaining the civil nuclear realm. For even though it can be compelling to construe nuclear actors as strategic and self-interested deceivers, it jars with almost any close ethnographic engagement with nuclear experts themselves. Nuclear engineering is manifestly not tobacco science, and critiques of nuclear energy lose much of their force insofar as they demand we understand most nuclear experts as less earnest, well intentioned, or self-interested than their critics.

This is not to say that nuclear expertise is beyond critique, of course. It is simply to suggest that in order to understand its shortcomings it is useful to combine the insights of agnotologists with those of a complimentary literature. This is the science and Technology Studies (STS) literature (e.g. Hackett et al. 2008), which draws heavily on the insights of philosophers and historians such as Bloor (1976) and Kuhn (1962), to explore the sociology of expert knowledge. Its central tenet being that the hard sciences' rigorous methodologies cannot keep technical ‘facts’ from being malleable and interest-laden.

It is difficult to draw firm boundaries around the STS and agnotology literatures, which overlap in many respects, yet there are undeniable differences in emphasis. Broadly speaking, STS – born earlier than agnotology, at time when the idea of sociologists dissecting technical knowledge-claims was more controversial – is less assertive than its intellectual sibling. Among its earliest principles was a ‘symmetry condition’ (Bloor 1976) whereby it strove to remain impartial in respect to the ‘truth’ or ‘falsity’ of specific knowledge-claims and declined to make normative assertions or value judgements about them.[30] Such generalisations are coarse, but it is probably fair to say that where the agnotology literature is interested in manipulation and deception, the STS literature is more interested in ambiguity and interpretation.[31]

Relative to agnotology, STS places more emphasis on the idea that evidence is ambiguous, distributed and contestable. Rather than assert that actors are actively denying or obscuring ‘true facts’, it is more concerned with exploring how they negotiate between the multiple valid interpretations of ‘truth’ that are latent in the available evidence. It recognises that every actor in a technical debate is working with partial data and is interpreting that data through a contingent paradigm (albeit usually in ways that reflect their self-interest). STS offers a valuable perspective on nuclear energy, therefore, because by dispensing with the premise that there is a ‘truth’ that is

[30] STS has incrementally retreated from this position in recent years (e.g. Collins & Evans 2002) but it has done so slowly.
[31] Or, put another way, STS is more interested in misinformation than in disinformation.

somehow being occluded, it illuminates how knowledge-claims can be political even if the actors producing them are not. It shows how even trustworthy experts might produce untrustworthy knowledge, especially where there are institutional interests that systematically privilege some voices over others.

It achieves this in various ways. Firstly, it encourages critics to recognise the genuine ambiguity around issues such as radiological mortality, where honest experts can draw extraordinarily divergent conclusions simply by accepting different premises pertaining to esoteric judgements in outlying specialties of which they are unlikely to have intimate knowledge. Secondly, and slightly more subtly, it highlights the bounded and distributed rationality of nuclear expertise. It invites attention to the fact that politically salient nuclear knowledge-claims are actually aggregations of many smaller claims, each produced by a broad array of different parties. It reminds us, moreover, that the aggregation of these disparate and specialist claims depends on them being reduced to what Latour (1999) calls 'circulating references': standardised metrics, stripped of their uncertainties in ways that other actors are not always able to recognise. The result being that the salient knowledge-claims can assume a political character in ways that are largely invisible to the actors concerned – a product of the ways its constituent parts move around networks getting translated and reduced at the interstices between actors.

We should note that understanding nuclear knowledge in this way does not necessarily exclude an agnotology-type analysis emphasising denial and disinformation. The STS literature recognises that there are practical, conventional routines by which societies declare some knowledge-claims to be valid.[32] Insofar as institutional actors work to keep 'open' debates in public that they privately consider to be 'closed,' therefore, the STS literature might reasonably speak about active 'deception' in ways that echo the arguments of agnotologists.

As outlined above, however, an STS perspective is valuable because it also allows for nuclear expertise to be skewed without there being an active deceiver. Critics might argue that this leaves STS impotent as a critical tool, but this ignores the fact that a critical or normative gaze requires neither 'blame' nor 'certainty'. For even if we adhere strictly to Bloor's symmetry condition and reject the idea that one side of a technical debate has more credibility than another, we might still recognise that uncertainty itself has normative and critical implications.

[32] A process often referred to as 'closure' (Collins 1985; Latour 1987), whereby controversies coalesce around a consensus over time. To say that a debate has reached closure is not to say that it has been definitively proven or is beyond repeal, yet some argue that it represents the most practicable form of authority available (e.g. Collins & Evans 2002).

This is because uncertainty is key to nuclear policymaking in a way that it is not for almost any other technological or scientific enterprise. Even the smallest ambiguities become actionable when contemplating the potential loss of a city the size of Tokyo. So it is that policymakers can, and should, make decisions about nuclear energy on the basis of its uncertainty alone. From an STS perspective, therefore, the true ‘deception’ lies not in misleading assertions that nuclear reactors are reliable or that radiological pollutants are relatively harmless, but in the deceptive impression that these assertions are uncontroversial facts – something that even their proponents know to be false. An STS critique of the nuclear industry, therefore, would take issue not with its facts per se, but with its promulgation of certainty, and with its efforts to maintain that appearance of certainty in the wake of seemingly disconfirming evidence. For it would be unfortunate indeed if, as Sloterdijk (2000: 108) suggests: ‘the only catastrophe that would be clear to everyone would be the catastrophe that no one survives’.

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