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Responsibility and Nanotechnology

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Abstract
In this paper we argue that the concept and practice of responsibility is being transformed within science and engineering. It tells the story of attempts by nanotechnologists to make responsibility 'do-able' and calculable in a setting where the established language and tools of risk and risk analysis are seen as inadequate. The research is based on ethnographic participant-observation at the National Science Foundation-funded Center for Biological and Environmental Nanotechnology (CBEN) at Rice University in Texas, during the period 2003 to 2007, including the controversies and public discussions it was engaged in and the creation of the International Council on Nanotechnology. CBEN began as a project to study 'applications' of nanotechnology to environmental and biological systems, but turned immediately to the study of 'implications' to biology and environment. We argue here that the notion of 'implications' and the language of risk employed early on addressed two separate but entangled ideas: the risks that nanomaterials pose to biology and environment, and the risks that research on this area poses to the health of nanotechnology itself. Practitioners at CBEN sought ways to accept responsibility both as scientists with a duty to protect science (from the public, from de-funding, from 'backlash') and as citizens with a responsibility to protect the environment and biology through scientific research. Ultimately, the language of risk has failed, and in its place ideas about responsibility, prudence, and accountability for the future have emerged, along with new questions about the proper venues and 'modes of veridiction' by which claims about safety or responsibility might be scientifically adjudicated.

Keywords
anthropology of science, environmental science, materials chemistry, nanotechnology, responsibility, risk, safety

An environmental engineer with an interest in membranes and a chemist in search of a transmission electron microscope (TEM); a 200-year old US chemical company and a multinational re-insurance corporation concerned about the future risks of a new science;

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a vial of human b2 microglobulin from Ireland and polymer-coated quantum-dots from Munich; a mercurial, charismatic Nobel Prize-winning scientist and some timely *US News and World Report* rankings; social movement activists and corporate managers meeting in Tokyo and Houston; a 'virtual journal', a database, a roadmap, and a blog; a public relations firm and a novel governance structure; a US government-funded engineering research center and a well-dressed man from L'Oréal.

What sounds like a trailer for a summer thriller of international intrigue is actually the cast and set (the *actants,* perhaps, rather than the actors) for a story of responsibility in nanotechnology. Responsibility is a vague and polyvalent term and yet its frequent appearance not only in nanotechnology but also in phrases such as 'collective responsibility', 'Responsible Care®', or 'corporate social responsibility' suggests that there is broad and relatively recent cultural concern for achieving some putatively *new* form of it. What might it mean that this vague notion seems to govern action and ideas in science and technology, corporate strategy, or social movements? In this paper we ask: How is responsibility being made 'do-able'? Is responsibility being transformed into a calculable or formalized set of practices? How are these practices related to prudence, precaution, or preparedness? This paper addresses these questions by looking in detail at the case of environmental and biological implications and applications of nanotechnology, as they have emerged in the past 6 to 7 years.

There obviously are multiple meanings to 'responsibility' circulating today, but there has been little attempt to empirically specify the diverse practices emerging around it. Corporate social responsibility, for instance, has emerged as a powerful demand amongst large multinational corporations (Watts, 2005; Welker, 2009) and collective responsibility has been discussed with respect to environmental governance (Pellizzoni, 2004; Pellizzoni & Ylönen, 2008). The case we explore here examines practices of responsibility in emerging sciences – specifically nanotechnology, though our claims are applicable to domains such as synthetic biology, personal genomics, and the new neuroscience research.

The motivation for an analysis of responsibility emerged from our long-term ethnographic research alongside practitioners in nanotechnology as they tried to disentangle the implications, risks, perceptions, precautions and precautionary principles, responsibility, morals, and ethics of their research. Ultimately we observed and participated in efforts to define new problems, create new venues for research, and channel concerns from a wide variety of social actors into the heart of nanotechnology research. It should not be surprising that these actors were drawn immediately to the language of risk but what is more surprising, we suggest, are the ways risks and risk analysis have failed in this domain, and how new practices of 'do-able' responsibility have started to emerge.

The language of risk has become unmistakably prominent in public life in the last several decades. From grand sociological diagnoses of Ulrich Beck (1992) to the practical tools of risk management in finance or insurance, to forms of individual risk assessment (such as genetic risk), dialogue, discourse, and practice are saturated with the ever-more sophisticated, sometimes contradictory, language and techniques of risk. Recent scholarship has noted changes in the ways *calculable* and *incalculable* risks are assessed and treated (Beck, 1992; Luhmann, 1993; Baker & Simon, 2002; Lakoff & Collier, 2008). Among others, Collier (2008) notes the difference between 'archival-statistical' analyses of risk and 'enactment' and scenario-based modes of knowing risk;

Diprose et al. (2008) point to 'prudence' as an organizing theme through which incalculable risks of catastrophic nature are being governed; and environmental governance has confronted multiple ways of knowing risk (Jasanoff & Long Martello, 2004). It is clear that there is a wide diversity of both 'modes of veridiction' and 'modes of jurisdiction' (Foucault, 2008), which are related to particular venues (from the Environmental Protection Agency [EPA] to a corporate boardroom or a laboratory) and different national contexts (Jasanoff, 2005).

While the diversity of approaches to understanding risk is increasingly well understood, what has not been studied is risk's complement. Risk is very often part of a pair: risk *and* responsibility. Wherever risk is salient, responsibility is its implicit shadow. Measuring risk allows individuals and organizations to make *responsible* choices; taking unnecessary risks is seen as irresponsible; improper or inadequate risk assessment can lead to fault and hence *responsibility* for harm. Calculable risks construct a responsibility-as-liability for past harms, and incalculable risks induce a responsibility for future harms – perhaps an impossible one. Wherever there is risk, there is responsibility. But for all the work on risk, from the rigorously mathematical to the luminously philosophical, responsibility has received comparably little attention. Responsibility is not subject to the same kind of 'calculability' as risk. It is rarely approached as something that must be measured, made visible, or formalized. In individual terms 'responsibilization' under neo-liberal governance has received much attention in the literature (O'Malley, 1996; Rose, 1990; Miller & Rose, 2008; Shamir, 2008). However, responsibility as a collective problem does not easily fit into these models. While 'collective risk' and the distribution of risks across a population are well-understood concepts, collective responsibility or the distribution of responsibility is much less well understood. Indeed, the vagueness of a term such as responsibility can be a source of strength, as Cynthia Selin (2007) points out, for participants in the process of constructing or combating different expectations about what nanotechnology is or should become.

The story we tell here is about one group's attempt to become responsible. They did not set out to do this; and they do not always use the word 'responsibility', but the evolution of this research project over the course of several years reveals a great deal about how the language of 'risks' and 'implications' has failed to work (for the scientists themselves, not only for the social scientists observing their work), and how a new set of practices of responsibility have emerged. It was during a very telling fieldwork conversation that our attention was first drawn to the relevance of responsibility: it was a fear of being asked to take on 'too much responsibility' that was the pregnant conversation-stopper. From then on, it was the frame of the tractability or 'do-ability' of responsibility, we argue, that allowed us to make sense of their actions, choices, and language. For these nanotechnologists, the pertinent risks were undefined, potentially unknowable, and certainly not solely an issue of individual behavior. 'Risk', they claimed, was not a question of individual ethics in the practice of science, but the problem of *collective* responsibility and a mode of veridiction (a proper way of testing truth of claims about responsibility) for fundamentally novel threats. It is for this reason that they turned (and we turn with them) from the language and tools of risk to an investigation of the making of responsibility.

Our ethnographic research was conducted at the Center for Biological and Environmental Nanotechnology (CBEN) at Rice University in Texas, from 2003 to 2007. We look in detail at the formation of CBEN, the controversies and public discussions it was engaged in, and at the creation of the International Council on Nanotechnology (ICON) as an independent 'multi-stakeholder' entity focused on issues of responsible nanotechnology. CBEN started life studying applications of nanotechnology to environmental and biological systems. Before long, it was the implications of nanotechnology research that was driving its funding requests. We show how the notion of 'implications' and the language of risk employed early on addressed two separate but entangled issues, which then demanded two separate responsibilities: first, the biological and environmental risks that nanomaterials pose, and second, the risks that such research poses to the health of nanotechnology itself (often referred to as 'risks of public perception'). What came to be implicitly demanded of the participants therefore was both the responsibility to protect science (from the public, from de-funding, from 'backlash'), and the 'social' responsibility to protect the environment and biology through scientific research.

Responsibility: Individual and Collective

While responsibility has received far less attention than risk, it has not gone unnoticed. However, it is important to distinguish approaches to collective and individual responsibility. The latter is the subject of an extremely rich set of debates in moral philosophy concerning the imputation of actions and individual accountability for actions or chains of actions. John Martin Fischer (1999) provides an excellent overview of recent work in this field and its place in the tradition of ethical and moral philosophy generally. Interest in the problem was re-inaugurated by Peter Strawson's famous 1962 paper 'Freedom and Resentment' and the literature has blossomed since then. Rarely is this philosophical approach explicitly conjugated with the problem of risk, even if the implicit connection between discourses of risk and the demands of individual choice is now abundantly clear (Franklin & Lock, 2003; Jain, 2006; Rose, 2006). *Collective* responsibility, by contrast, has been addressed in only a handful of places. Richard McKeon (1957) and Paul Ricoeur (2000) have placed the problem in historical light, in the context of 19th century concerns with insurance and liability and 20th century concerns about the responsibility of nations to one another following World War II (Kelty, 2008). Hans Jonas (1984) has addressed the problem of responsibility for 'incalculable' risks such as ecological catastrophe, terrorist attacks, or global health pandemics, and argued for a thorough rethinking of the concept and its principles. In Anglo-American philosophy, Joel Feinberg (1968) initiated a small debate about the possibility of collective responsibility, to which others have responded (Arendt, 1987; French, 1972; May & Hoffman, 1991), and more recently, Hans-Otto Apel has introduced the concept of co-responsibility (Strydom, 1999). Collective responsibility sits uneasily with the core concepts of imputation and accountability that are employed to analyze individual responsibility. The question of imputation is confounded by the fact of social and technical complexity. In the case of nanotechnology this has been a core feature of debates (largely conducted in connection with science fiction) about self-replication and out-of-control technology, but it is also visible in the more realistic scenarios of environmental pollution and the potential biological toxicity of new materials. Similarly, the question of accountability is confounded by the distributed, semi-coordinated and largely unregulated system of scientific and technical investigation, and the rush to commercialize and scale-up production of new nanomaterials. In all of these cases, responsibility cannot be approached through the decisions of individual actors, even if it is not clear where else to look.

It is tempting to see 'responsibility' as another name for the changing relationship between science and society, as in the work on Mode 1 and Mode 2 knowledge of Nowotny et al. (2001), or the promise of moving public engagement 'upstream' (Breggin & Carothers, 2004; Wilson & Willis, 2004; Macnaghten et al., 2005; Bennett & Sarewitz, 2006; Burri, 2007; Pidgeon, 2007; Rogers-Hayden & Pidgeon, 2007), or the co-construction of science and its publics (Jasanoff, 2004). However, following Latour (2005), we approach responsibility and nanotechnology in the same frame, and argue that in reshaping the relationships between the existing disciplines that make up nanotechnology (materials chemistry, environmental engineering, bioengineering), these participants are also remaking responsibility. Separating the science from the ethical deliberation merely obscures the practices of both as they occur.

Such a separation has nonetheless occurred, as a sub-field of research on the ethics and social implications of nanotechnology has emerged in the last 4 years. In the attempt to differentiate the properly 'ethical' from environmental health and safety (EHS) research, nano-ethics and nano-STS have suggested that research on environmental and biological safety of nanotechnology should not hold center stage as 'ethical' questions. The reasons for this are clear. An exclusive focus on environmental or worker safety *qua* ethics is an unacceptable narrowing of the field that excludes many questions. The chemists and engineers interviewed in this study agreed; they recognize this narrowness and welcome any definition of ethics that would broaden the debate, but they also sought to make the existing questions about safety more precise. Though we don't address them here, questions of social justice and of the ways in which nanotechnology can be pursued to achieve it became explicit in other aspects of our work (Kelty, 2009; Lounsbury et al., 2009). Furthermore, the emergence of these new 'ethical' fields – and the authors' own involvement in them – are in fact related to the story told in this paper. The unfolding of the events in CBEN, described herein, gave great momentum to the creation of the fields of Nano-STS and Nano-ethics during this period, and helped define how and where the language of responsibility could be used. However, it is also clear that social science researchers have perhaps missed the fact that EHS research is itself an attempt to respond to demands for 'ethical' science, 'responsible' science, or 'safe' science, and not only a technical pursuit.

By shifting the frame of analysis towards responsibility, we suggest that scientists and engineers in nanotechnology are exploring exactly this landscape of 'do-able' responsibility – and in concrete ways that ethicists sometimes insist they neither want nor need to do. What's more, these practices imply something much more complicated than an application of existing models of risk (or existing problems in ethics) to nanotechnology; they imply the creation of new forms of responsibility. If the shift from 'danger' to 'risk' is about making the future calculable and hence tractable (Luhmann, 1993), then a similar shift from 'safety' to 'responsibility' is at work in this story.

Figuring out Responsibility

June 2007: A Beer Garden in Zurich

Vicki Colvin, materials chemist and director of CBEN at Rice University in Houston, and Ken Dawson, a chemist from University College Dublin, are discussing responsibility over drinks. In particular, they are brainstorming about how to bring scientists worldwide together to address urgent research needs for understanding the safety of nanoparticles; it is urgent, both because safety is at stake and because it is clear to these two chemists that hardly anyone else is studying the issue.

Colvin and Dawson are not activists. They are neither exceptionally committed to safety nor trained in fields whose primary research focus is safety. Indeed, the discussion over beer makes it clear that both of them share a sense that they are being asked to do something much greater than simply pursue science where science takes them, but to *become responsible* for where this science is heading.

The pair is in Zurich for a meeting organized by ICON (an offshoot of CBEN) and hosted at the multi-national re-insurance corporation Swiss Re's Global Dialogue Center on the silver western shore of Lake Zurich. The 'Research Needs Assessment Workshop' was designed in order to bring together scientists and 'stakeholders' from multiple scientific fields, corporations, and civil society groups to address the basic research needed to adequately study the environmental and biological effects of nanoparticles. This second workshop focused on mapping the *mechanics* of nano-bio interactions and separately, the role of different biological systems (cellular, tissue, whole organisms, the environment) in such interactions. The first of these workshops was held at the National Institutes of Health (NIH) in Maryland in January 2007 and identified 'classes of nanomaterials with common properties … and potential "hot spots" in their lifecycle' which would be used as a basis for setting the goals of the June workshop.

Dawson and Colvin are idly wondering about setting up a large international Foundation, and they agree that, based on the day's meetings, the amount of work necessary is daunting and, they repeat, urgent. The first day of meeting confirmed just how much remains to be done in order to develop the kinds of models that will, as the ICON website says, 'predict effects – adverse or desirable – of engineered nanoparticles upon interaction with biological systems'. 'Predictive nanotoxicology' is one label being tried for size; 'Quantitative Structure–Function Relationships' is another. At stake is making the study of the biological and environmental characteristics of nanomaterials into a science. For Colvin and Dawson and many others at the workshop, this goal goes beyond a regulatory or 'ethical' need to help society deal with the implications of nanotechnology as it progresses. It encompasses a predictive science working on compelling fundamental issues at the interface of materials chemistry, environmental science, and systems biology. An international Foundation with the right prestige and lots of money might just be able to jump-start the field.

'What about a model like the X-Prize for space tourism?' asks McCarthy (who is attending as an anthropologist and observer). Colvin and Dawson shake their heads: 'It won't work, it encourages competition when what we need is consensus – we need to have scientists working together, scientists around the world working in step, at least for a short while', says Colvin. She talks about the need for a fundamental shift in how science happens. She talks about her plans for 'open source nanotechnology' and the idea of radically changing the way technology is developed, innovated, and transferred to the developing world. Similarly, Dawson is also involved with EU-funded and EU-wide, multi-million-Euro collaborations.

Pushing the question further, McCarthy wonders, why such urgency? She asks: 'What is the problem? Is it because there's a need to keep beneficial results in keeping with or ahead of negative results which, if they became dominant, could derail nanotech?' Dawson and Colvin argue that no, there's no agenda. They are not looking to have either positive or negative findings – just findings. Findings provide the warrant for making decisions responsibly; without them responsibility does not function the way it is supposed to.

Dawson talks about the 'the dark days' he experienced recently, upon publishing a paper describing the effects of nanoparticles on amyloid plaques – evidence that nanoparticles can cause protein fibrillation of the kind associated with Alzheimer's and Parkinson's diseases (Linse et al., 2007). He explains that, soon after publication, he received a call from senior officials asking quite seriously whether there was now a need for a moratorium on nanotechnology. He shakes his head. Colvin empathizes and qualifies the feeling better – as if at such moments she feels like she has *more responsibility than she's supposed to have*. Both fall silent.

Colvin is familiar with this sentiment – this strange calling. It is at the heart of the challenges that have faced her institution, CBEN, and the organization that has grown out of it, ICON. Dawson's paper is, in fact, the central biggest event in ICON's 2007 roster: a result of major importance in an important journal in the USA (*Proceedings of the National Academy of Science*) which requires, as ICON sees it, responsible treatment by scientists, the press, civil society, and corporations. It is exactly the kind of event that ICON was established to deal with. Over the last 4 months, ICON had created a 'backgrounder' and a commentary published alongside the paper in *Proceedings of the National Academy of Sciences* (Colvin & Kulinowski, 2007), fielded journalists' queries about the research (forwarded by Dawson to ICON), and strategized about how to get the message out in responsible fashion. It was, according to the director of ICON, Kristen Kulinowski, the first true test of the novel governance structure at ICON as well – meaning that the backgrounder and commentary, while written by Kulinowski and Colvin, was officially endorsed by all the stakeholders in ICON – government, civil society, corporate, and academic. It was a process not without tension, as members attempted to dissent individually, but were ultimately forced either to yield to the governance structure or to leave the organization entirely.

Part of Dawson's concern was local: he talks with great feeling about seeing the connection between these events and Ireland's future, and Ireland's investment and position in technology. Underlying his worry is the reality that explicit scientific findings, no matter how insufficiently mature they are, must be published. Often however, the interpretation of such findings in the public domain can be driven by forces other than scientific concern – bad news without reason, for any advanced economy based on technology. That kind of responsibility seems unjust: to be confronted with a danger so great, a 'knife edge' as Colvin called it, that perhaps nothing should be said at all. What if the publication of this paper led to the collapse of an entire research endeavour – one he has helped to build and benefits from as well? But, says Colvin, if it had been a different man than Dawson, the outcome from the publication of his paper might have been much different, more catastrophic. They discuss the emotion involved in all this. *Dawson wants somebody to take responsibility.* This is partly what the Foundation would do. He insists that there needs to be such an authoritative – responsible – voice. Why don't others – the government, corporations, other scientists – hear the call as clearly as he does? Colvin isn't so sure about his worry. She argues that if risk is communicated the right way people would take it on board. All that's needed are data and clarity to point out why nano brings benefits but that there are risks too – much like the scenario she sees pharmaceutical companies dealing with all the time. She thinks that people are more tolerant of risk than they are given credit for.

Responsibility appears to mean multiple things in this conversation. On the one hand, there is the demand for a responsible approach to understanding nanomaterials, a need for research on the fundamental interactions of nanoparticles and biological systems. On the other hand, Dawson, Colvin, and ICON are seeking new ways to ensure that public reactions to these results are balanced – civil society reactions, corporate reactions, investor reactions, government agency reactions. It is a kind of double bind: pursuing research on the implications of nanoparticles is the responsible thing to do, and yet to report those results without some kind of reliable process for ensuring a balanced reaction and understanding of the public is irresponsible (Fortun & Fortun, 2005). Hence Colvin's feeling that she has *more responsibility than she's supposed to have*.

These two forms of implication – the risk of nanotechnology to human and environmental health, and the risk implications research poses to the health and funding of nanotechnology – have been entangled in complicated ways since the founding of CBEN. The June 2007 meeting in Zurich represents a moment of success in making nanotechnology responsible – untangling these different risks, and perhaps moving beyond the language of risk. Even though there is anxiety and worry, even though it isn't clear yet what responsibility is or who should be taking it on, the meeting is the result of a complex, long-term attempt to figure it out. The meeting can be seen as a kind of 'ethical plateau' (Fischer, 2003): a space carved out and created in response to a demand, in which actors from multiple domains meet, a place bounded by the 'horizons of ethical issues posed by the intersection of several technologies, their institutional formattings, and their deployments through markets and other mechanisms' (Fischer, 2003: 146). In this case, the intersection includes: corporate representatives, government agents, university scientists and social scientists, civil society actors, a novel organization (ICON), a set of proposed research questions and some recent scientific papers, including a potential controversy averted and an emerging plan for future research.

What distinguishes these meetings from other discussions of ethics or responsibility, however, is their explicit and *simultaneous* focus on the governance of nanotechnology and fundamental research into nanotechnology. ICON is creating concrete practices, plans, techniques, and governance structures within which the demand for responsibility becomes eminently do-able, and in turn renders the problem into something that that scientists can pursue in labs, funders can fund, corporations can implement, and activists can monitor.

Contrast this with the previously dominant stories of responsibility in nanotechnology, starting with K. Eric Drexler and the Foresight Institute, amplified by Bill Joy's 2000 article in *Wired* and Michael Crichton's thriller *Prey* (Joy, 2000; Crichton, 2002; Bennet & Sarewitz, 2006). These visions of nanotechnology include both a utopian component, a novel machine that could molecularly manufacture anything, and a dystopian one, the doomsday scenario of life rendered into 'grey goo' by self-replicating nanobots (Drexler, 1986). But the entirely theoretical character of the utopian claims is mirrored in the fact that of the dystopian ones have never resulted in any practical action of any kind. ICON and CBEN, by contrast are intent on finding a *do-able* responsibility. The 2007 meetings, however, are not the culmination of a vision, but a stage along the way to figuring out responsibility in nanotechnology that had begun much earlier, under different conditions and for very different reasons.

A Tiny Just-So Story: Proposing CBEN

Vicki Colvin didn't want responsibility; what she wanted was a TEM.

> The real reason that I went after CBEN and I looked for a Center was because to look at nanoscale objects I needed a transmission electron microscope. And I needed it to work. It was the most important piece of equipment for all of my research and the one at Rice was broken and nobody knew how to use it. So I was flying to Berkeley or Tennessee and I was very frustrated that we didn't have infrastructure on campus for nanotechnology. So I went to the Deans and I whined and I complained and they said, well, raise money. So I went to my National Science Foundation program managers and they said we can't give you money to do that. The only way you can really get money to build infrastructure is to get a Center grant because then you can set money aside to pay for people to run the instrument. (Vicki Colvin Interview #1, hereafter VC#1; all interviews are listed in the Appendix)

Colvin had been recruited to Rice University in Houston, Texas, as part of its growth in nanotechnology that began in the late 1980s, but accelerated considerably with the Nobel Prize awarded to Richard Smalley (together with Robert Curl and Harold Kroto). Rice has never been a large school (about 4000 students and 700 faculty); a school the size of a liberal arts college, but conducting research competitive with much larger schools. In part because of its small size, the research infrastructure was fairly hierarchically controlled. For instance, there was an Atomic Force Microscope in Richard Smalley's lab, but as Colvin pointed out: 'his rules were I could use it between the hours of 2am and 6am, so I would come in with my students at 2am, the junior faculty we're really kinda under his foot'. Colvin's research area was materials chemistry and optics of materials; for this she needed a TEM, but to get a TEM she needed a Center – but what kind of Center?

Colvin began to participate in the National Science Foundation (NSF)'s Center activities, meeting program managers, doing material science and engineering Center reviews, getting involved with a Science and Technology Center review panel, and generally gathering experience and data on Centers. So when the NSF announced in 2000 it would fund six new Centers in nanotechnology, Colvin saw her opportunity:

VC: … and I'm like okay, this is a dream for Rice because it's got Rick [laughs]
CK: it's got Neal Lane [former head of the NSF and Science Advisor to Clinton]
VC: it's got Neal Lane. We got stuff going on. It will just be a straight shot if … I know how to package it. So I went to Rick and the big issue was: what it would focus on .... At Rice we tend to think we're the leaders and we're really not the leaders in nanotechnology. I knew what we were good at. I knew we had Rick, he's very vocal, very visible but I knew that we couldn't compete with Berkeley or Columbia or Cornell particularly in the area of electronics .... So I literally didn't know what to make it about, but I sat down and got out *US News and World Report* and I looked at the rankings of all of our departments and I realized that biological and environmental engineering were among the top-ranked Departments in our campus. (VC#1)

Colvin's focus on these two disciplines, bioengineering and environmental engineering, emerged strategically – she knew who not to compete with, and she knew the NSF would demand that the proposal make the best and most creative use of existing expertise. Hence, the big science focus on molecular electronics and carbon nanotubes was out, even though the Patron Saint of the Center would be the Nobel-winning co-discoverer of C_{60}.

> [Our research group] already had collaborations with environmental engineering through Rice, through Mark [Wiesner] and I also knew Jennifer West pretty well in Bio-Engineering and I knew they were early but I figured it would be different so I literally did BioE and environmental for that, it was very strategic, just decided we could, we would look different than everybody else who was going to do molecular electronics. And I had to fight with Rick on this. Rick wanted it to be physics. He wanted to do devices, but I convinced him that we had early advantage in this area and that was actually really due to Jennifer's work more than Mark's. He [Smalley] really never liked the environmental stuff from the get-go. (VC#1)

Mark Wiesner was in Civil and Environmental Engineering, and he had not come to Rice as a nanotechnologist. His career began in the relatively unglamorous field of membrane science (Van Lente & Rip, 1998). Wiesner had been dragged into nanotechnology by chemist Andrew Barron, who was at the time (the late 1990s) interested in writing a grant proposal to the EPA's 'green chemistry' program. But Barron needed someone who knew something about the 'green' part, and turned to Wiesner for help. According to Wiesner he was immediately intrigued:

> [Environmental Engineering] had tackled water and it sort of tackled air, and then variations of like, groundwater, hazardous waste. And, most of these things were things that had to do with problems we created along the way, but I got really interested in the idea that, as we make products, the materials involved to make those products, what's the origins of those materials, how do they get used and how do they get disposed of, and can we think this through from the beginning in way that will minimize future environmental problems of the variety that environmental engineers up to now had spent all their time cleaning up after?' (Mark Wiesner, Interview #1, hereafter MW#1)

Baron and Wiesner collaborated on the creation of a new class of membranes made from alumoxanes and ferromoxanes – materials made from aluminum and iron respectively, and particularly well-suited to filtering water. With Barron's expertise in the chemistry of these two substances, and Wiesner's in making and testing membranes, the two were able to create membranes 'from the bottom up' – meaning that they could use the techniques of chemistry and chemical engineering to produce a membrane, rather than taking an existing substance and taking it apart or processing it into a filter (Bailey et al., 2000; Cortalezzi et al., 2003). The ability to finely control the creation of the tools for cleaning water (or more generally, any process of filtration) led Wiesner to think of this as 'paradigm shifting work' – away from remediation and towards engineering of environmentally clean and safe processes and materials.

I wanted to take my research group in that direction. Andy and I were continuing to collaborate. And then one day at a cocktail party, Vicki Colvin and I started talking and she said,

> Well, there's an NSF program in nanotechnology and I'm going to submit a proposal on it, and you know, looking around the website, you look like the only environmental person that makes sense in terms of, you know, that has this orientation. Do you want to work together on this? (MW#1)

Together Wiesner and Colvin began work on the proposal, along with bio-engineer Jennifer West, whose work in the area of biomaterials and tissue engineering intersected with Colvin's work through the object of the gold nanoshell. Gold nanoshells were nanomaterials with 'tunable' optical properties (that is, the thickness of the shell determines the wavelengths of light absorbed or reflected) that West was investigating for potential applications to cancer therapy. As they began to plan a strategy for the Center proposal, the input of both West and Wiesner raised the issue of studying the environmental and biological impacts of materials for the first time.

> It was at those meetings that Mark started to talk about environmental impact … I think I remember exactly the time because Jennifer was talking about her materials going into the body and about FDA [Food and Drug Administration] issues of whether it was a device or a drug and that they would have to do a lot of toxicity studies and then Mark was saying, you know, that's going to be an issue too and, so it was really the bio-engineers seeing FDA regulation as an issue for them and Mark echoing that from an environmental engineering perspective … both of these technology areas were going to be limited by potential risks and there was no reason to think we weren't behind that. And Rick rarely came to these meetings. (VC#1)

As the Center proposal took shape, it slowly became clear that it would include not only a substantive focus on bio-engineering and environmental engineering applications of nanotechnology (for example, membranes and nanoshells), but also a component devoted to studying toxicity, environmental effects, and 'implications' more broadly.

It was not obvious, however, that such research would be part of the *core fundamental research*. According to Colvin especially, it was 'just obvious' that the Center would look at biological and environmental impact issues 'early, because it was going to affect our commercialization trajectories'. In the early stages of composing the proposal, however, Wiesner considered the most important meaning of biological and environmental nanotechnology to be fundamental research into the environmental and biological properties, toxicity and exposure profiles of nanomaterials. Such research should not simply be conceived of as applications to existing problems. Colvin, Smalley, Wiesner and Jennifer West all came to the proposal with different questions and definitions of 'basic' science.

Rick Smalley's main interest was to exploit the novelty of including biology and environment within the domain of what he conceived of as primarily a chemistry and chemical engineering Center – hence the need in the proposal for a '35,000 foot' overview of the 'wet–dry interface' replete with an image of a flag planted symbolically at the border between wet and dry ('we must have drawn that flag a thousand times', said Colvin, emphasizing how important Smalley found this conceptualization). The focus, however, was strictly on novel engineering applications of new nanomaterials.

Meanwhile Wiesner recalled it being very difficult to include the 'implications piece' in the core of the proposal over the 'applications' of nanotechnology to environment and biology:

> Vicki's original idea was that she wanted me to group together people that were going to do technologies [for biology and the environment], where we would be using nanotechnology for good, [laughter] and every time I'd write the evil part [laughter], and it would keep getting kicked back, they would say, well we didn't have enough room, let's cross that out. And it was really difficult to keep it in [the proposal]. (MW#1)

Wiesner eventually triumphed in terms of including the 'evil' implications of nanotechnology for biology and the environment only because he understood the stakes: he had already pursued research on applications, such as using nanomaterial membranes for environmentally beneficial purposes. But for Wiesner, it was a principled stand to include research on the safety of nanomaterials, born of long experience as an environmental engineer devoted to creating safer processes and products.

Colvin, finally, was far more interested in strategy and *realpolitik:* the rules of the proposal form demanded the identification of strategies for achieving milestones and avoiding roadblocks, and so the issue of applications versus implications entered into the proposal through that channel:

> I had to have a three-plane diagram, a commercialization plan to deal with roadblock issues and a roadblock was going to be public acceptance of technology, a road block was going to be the regulatory process so I had to address roadblocks in the planning of the Center, so I used [implications] that way – to fit with the strategic plan … you know, talk about what the limits and barriers are and how you're going to address [them], you know, Section 8, strategic plan, 10-pages, so I was …
>
> CK: [so you were] forced to imagine potential scenarios of roadblocks just to get [through the application?]
>
> VC: Yeah … that was coming out in what NSF was asking us to do and so the impact stuff of Mark's was just fitting because we needed it, but really it had legs in both areas of the Center because the bio-engineers were concerned about clearance of particles from a body, toxicity … and so the bio-engineer is like 'well of course we're going to do clearance studies and toxicology, because we're bio-engineers, you know, what do you mean you environmental engineers don't do that?' And it was a weird kind of disconnect

> and again it was this sense of, yeah it's obvious of course we're going to do that, which was more a bioengineering perspective so I think Jennifer [West] was a little bit quizzical about why it would be in its own project area and not just distributed. (VC#1)

Jennifer West was quizzical because Wiesner was attempting to fit 'implications' into the core of the research proposal – to make it *experimental* – as a form of fundamental research, and not only as a follow-on – a *test* – that would address road-blocks.

When the proposal was finally submitted, the responses from the reviewers were predictably polarized. For Colvin, this was surprising, and a bit confusing. She suggests one reason might be that Wiesner had written the implications part too strongly, perhaps emphasizing too much that 'we're going to go out and make really sure this stuff doesn't kill us all, you know … ' even though the positive reviews had clearly recognized the value and novelty of the idea.

> CK: and the negative ones, did they, did they explicitly say you shouldn't do this because it's a threat to … ?
> VC: nooo, of course not, no
> CK: But was that between the lines do you think?
> VC: it was a little bit between the lines. It was more that you shouldn't do this because there is no scientific content.
> CK: I see …
> VC: They would use different rules, or say: that there's nothing new about [this], of course we're going to do this. Why are you calling it out? Of course anybody's going to do this. It's kind of like, well, of course you're going to have to raise money to start a company. Why are you calling it out? It's a natural part of your path. It was more like it was [pause] they did not see it as an endeavor of its own, you do it at the end of the time. Downstream you run a toxicology test. Why is this science, right? (VC#1)

For Wiesner, the 'implications' piece was something that had historically become necessary – it was no longer acceptable to wait and see, to do the research at the end of the 'real' investigation – the 'implications piece' was also the scientific content of the research, not just a roadblock to be dealt with. For Wiesner, research into the toxicity and exposure profiles of, for instance, carbon nanotubes is fundamental research, full stop. As he puts it: 'because it's so new, you can sneeze on this stuff and find out something interesting (MW#2)'. The nature of that 'something interesting' is precisely at the heart of the tension. For materials chemists, the question of what a carbon nanotube does when it is dumped in a river, or when it approaches a cell membrane, seemingly has nothing to do with the characterization of nanotubes as such. For the materials chemist, one must answer the key questions about the particle itself, before asking about its relations. For the environmental engineer, on the other hand, the particle is only as good as its relations with a body or an environment. Understanding what new kinds of materials *do* when they see cells or are dumped in water is what makes them interesting – both for what they say about potential harm, and for what that proves about potential applications. Thus it is not a question of doing basic science followed by 'impact' studies that make clear what the potential risks are – for Wiesner, such research is prior to any positive or negative impact. Indeed it demands the most positive aspect possible, and the avoidance of making anything dangerous at all.[1]

For some reviewers, that message was clear, and according to Wiesner, it was one of the key reasons the proposal was eventually funded. But for other proposal reviewers, there was no such science here. Indeed, as Colvin repeated, they kept asking 'Why are you calling this out?' as if such studies were in fact already a routine and unexceptional part of scientific research – only downstream, after the action is over. According to Colvin, it was the idea that what CBEN was proposing to do was 'not scientific' that caused them to dig their heels in: 'those paper reviews saying don't do this, don't do this; or, it's not interesting. It was that "don't do this", it was "it's not interesting" [that convinced us to push it]. No it *is* interesting' (VC#1).

In the end, whether the idea was innovative or not was perhaps less important than Colvin's strategic instincts about the Center program generally:

> A hundred proposals came in. They got it down to 23 for the final proposals. Then they whittled it down to 12 to go to NSF … then in 2001 we went on reverse site in May and presented to a panel and I, I must admit, I pat myself on the back. I was totally right: There were 12 proposals, 10 on molecular electronics. I knew when we showed up that we were funded. (VC#1)

In the end, CBEN didn't pay for Colvin's TEM (though she did get one); what it did produce was arguably far more significant: the transformation of the meaning of nanotechnology generally, and materials chemistry of nanoparticles more specifically. It meant the beginning of an experiment in dealing with issues far beyond the planned scope of the proposal, up to and including testimony before the US Congress.

Getting to Yuck: CBEN's First Three Years

The 2000 founding of the National Nanotechnology Initiative and the funding of the NSF Centers meant that for the first time in nanotechnology's history there were now legitimate places for journalists, academics, and the public to turn for information about the subject – places replete with University credentials and the imprimatur of the US government. Of the 14 Centers funded in 2001–02 by the NSF, only CBEN had anything remotely like a focus on human health, environmental issues, or social implications. Only CBEN seemed to have anything to say about nanobots, smart-dust, and gray goo. As a result, CBEN found itself squarely at the center of a much more public discussion than the principals could ever have imagined.

Rather than turn away from that attention, CBEN members embraced it. Colvin, Wiesner, and the new executive director Kristen Kulinowski all began to speak widely and confidently about the need for the kind of research CBEN proposed to do – always in terms of creating a 'responsible' nanotechnology that would allow the benefits to accrue without the disasters imagined by critics. In 2001, just as the Center was 'standing up', Mark Wiesner convened a high-profile, international meeting on the environmental impacts of nanotechnology. There he raised a series of comparative cases – asbestos, DDT, and Freon – as ways of understanding potential pathways for industrial development and its environmental consequences.

> In December 2001 when we had the event, this was, you know all of the planets were aligned and this was really the first time, I believe, that anyone had articulated publicly the issue of not only how can you use nanotechnologies to do good things for the environment, but also what are the implications of these nanomaterials for the environment? (MW#1)

It was at this meeting that Wiesner and others raised the question of how to study the toxicity and environmental effects of nanoparticles, and whether they might have novel (environmental and biological) properties that no one had yet researched. At the same time, there was growing attention to this issue from a range of non-governmental organizations (NGOs) and civil society actors – most centrally the Action Group on Erosion, Technology, and Concentration (ETC). ETC had begun to release a series of papers and documents about nanotechnology, some of which raised strong concerns about its safety and regulation, and some of which quoted Mark Wiesner. A *New York Times* opinion piece that appeared on 19 August 2002, and which examined the increasingly vocal activities of the ETC Group, stated:

> ETC asserts that research suggests that the characteristics that make carbon nanotubes and similar nanoscale particles attractive candidates for carrying drugs into the brain could also allow such particles to transport toxins. It quotes Dr Mark Wiesner, a Rice Professor, as warning that Nanotubes, because of their needle like shape, could become 'the next asbestos' .... ETC's critics say the group has taken the concerns of Dr. Wiesner out of context. (Feder, 2002)

At the same time, Colvin and Kulinowski were developing a narrative about the research at the Center and its broader as well as scientific relevance, not only scientifically, but broadly. They began to speak widely and publicly about the issues the Center had been founded to address. Kulinowski wrote:

> By early 2003, after 18 months of operation, Center leaders had met with more than thirty companies and given over two dozen public talks about nanotechnology environment, health and safety. The message was always the same: nanotechnology has enormous potential to improve our lives but the risks of engineered nanoparticles must be explored in conjunction with the technology's development. (Kulinowski, 2007)

The message that Kulinowski developed would come to be known quite widely as the 'Wow to yuck?' trajectory (Kulinowski, 2004), and was developed very much in the context of the first public debates about nanotechnology in the US. Initially, the 'Wow to yuck?' trajectory was meant as a question – Will nanotechnology follow the same path as other technologies that have started out with a 'wow' and turned south when people realized the 'yuck' factor? Many people, however, read it as a prediction that nanotechnology would follow this path: they left out the question mark, according to Colvin (Rip, 2006: 350–51).[2]

The story was charming, and focused attention not so much on the implications of nanotechnology to biology and environment but on the 'implications of the implications': the idea that if we do not study the environmental and health risks of nanomaterials, the 'public' may lose trust, backlash may ensue, and in the ubiquitous example used in every case, supposedly go the way of genetically modified organisms (GMOs). This concern was most loudly voiced by corporations, such as Swiss Re, that had invested in GMOs (or insured such investments) and seen public politics and the resulting European Regulation adversely affect those investments.

The enormous amount of attention focused on the Center came in part as a surprise: scientists and engineers no doubt expect attention, but usually for the research they have already embarked upon, and not for the research they have yet to even begin. The 'Wow to yuck?' story revealed some of the confusion that was confronting CBEN early on: even as Colvin and Kulinowski traveled the world urging everyone to put resources and attention into studying the implications of nanotechnology in order to avoid a public backlash, their fellow scientists were begging them to *just shut up* about it in order to prevent such a backlash. As the message grew louder, the story more polished, and the venues more prestigious (culminating with Colvin's testimony before Congress in 2003 [Colvin, 2003]), the concern of fellow scientists grew more intense. Chief among them was Colvin's senior colleague Smalley, of whom she said: 'I'll never forget his words, he said, "You're throwing gasoline on the fire. *Just stop talking about it*"' (VC#1).

The attacks on Colvin and Wiesner came from multiple directions – from Smalley principally, from the university administration, from senior colleagues in the field, and even from their own NSF program manager, Mike Roco, who also asked them to stop talking about it in late 2002 and early 2003. Colvin began to blame Wiesner for accentuating the message, and for not presenting it in a politically balanced way. Wiesner also was subject to censure from the university and the NSF, culminating with, according to him, a request from Colvin to 'move into the background' and no longer emphasize the Center's work on the biological and environmental implications of nanomaterials. While Wiesner's work was never halted or questioned, his understanding of his embattled situation fueled his desire to focus on the implications. Perhaps most ironically, it was Colvin and not Wiesner who eventually turned her research most immediately to the toxicological questions around nanomaterials, in part because the heated debates were conducted in the absence of any real scientific data to argue about.

The culmination of this early period was Colvin's April 2003 testimony to the House Committee on Science and Technology about the 'Nanotechnology Research and Development Act of 2003' (Colvin, 2003). The testimony rehearsed the 'Wow to yuck?' question again, but it also made clear that the real risks of nanotechnology were not just that they might potentially harm biology or the environment, but that the fear generated by a poorly informed public could 'turn the dream of a trillion dollar industry into the nightmare of public backlash'. And this was precisely what her scientific colleagues were *accusing her of doing*. The testimony clearly identifies 'public backlash' as the central danger and the reason why CBEN pursues the research it does – in order to prevent such a thing. But 'public backlash' was clearly never part of the CBEN proposal or the research it funded. 'Public backlash', however, was what Colvin used to resist her critics' onslaught: implicit in the message is that public backlash comes from irresponsible development of science, and that failing to study the impacts of materials is part of that irresponsibility. Greater in risk than a cut in funding due to fear would be the destruction of an industry that did not adequately prepare for the risks it created – and this *requires responsibility* in science, in corporations, in government, in the media, and so on.

Colvin's testimony before Congress was not really about nanotechnology: it spoke of ethical and social issues, the GMO controversy, DDT, and asbestos, and public acceptance – not of membranes and nanoshells and buckyballs, nor even of the field of materials optics in which she originally worked. It makes reference to the Ethical, Legal and Social Implications (ELSI) funding provided by the Department of Energy (DOE) for the Human Genome Project, and more or less demands more funding for *social scientists,* and not necessarily for chemists and physicists. Colvin's initial experience with CBEN, in which it was suggested that the study of implications was not itself scientific, also appears in the testimony; but there she found herself broadening the demand and encouraging federally mandated funding of research in and on all sorts of implications. Somehow, a scientist who started a research center that focused on arcane and specific areas of research like membranes and nanoshells found herself subjected to the hottest public spotlight in the land, and placed in a position to criticize the government and her colleagues for their slow acceptance of responsibility.

Colvin, Wiesner, and CBEN were obviously not the only actors confronted with these issues. The virtue of characterizing responsibility in nanotechnology as an ethical plateau (Fischer, 2003) is that it captures a conceptual and practical space, organized by a calling, which many different actors jointly find themselves occupying: 'classic' nanotechnologists such as Drexler and his ilk, multiple scientific disciplines, social science and 'ethics' of science and technology, civil society movements and NGOs, government regulators, corporate research and development (R&D) and marketing representatives. At the time, all of these groups and individuals were focused on questions about new materials, the lack of standards for measurement and testing, the question of 'public' perception, the creation of new products, the regulation of toxic materials, all in the context of a [former] US presidential administration hostile to science and to environmental regulation, a scientific community terrified of losing prestige and funding, a corporate community steeped in imaginary memories of a GMO 'disaster' and civil society actors looking for the next one.

What started as a plan to create a new 'wet–dry' applications of nanotechnology, with the backing, if not the blessing, of Rick Smalley, ramified into a confusing space of different kinds of implications and a controversy about which were real and which were not and which required 'real' science and which did not. Throughout it all, the use of the term 'implications' and the language of risk became more and more confusing. In this context, the 2003 Testimony and much of Colvin's writing attempted to synthesize two different kinds of 'implications' into one message: on the one hand risks of nanotechnology to environment and biology (the kind of implications Wiesner initially saw as fundamental), and on the other risks *to nanotechnology* of pursuing such research in the first place. Colvin and CBEN synthesized the message into one: if we do not study the risks of nanotechnology to environment and biology, then the public backlash will grow and itself become a risk to nanotechnology. It was not clear, however, whether CBEN would be responsible for conducting research on both risks – and it is at this stage of figuring out implications that ICON began to emerge as a dimly perceived solution.

Figuring Out Implications: ICON

In 2003 CBEN applied to the NSF for supplemental funding in order to address the complex mix of implications. The activities taking up the bulk of Center participants' time and attention were not focused only in their laboratory research, but also on an array of confusing demands coming from diverse quarters of society. It is fair to say that figuring out what implications meant and how to address them started to occupy the core of the Center's activities, while the laboratory research remained focused on applications.

The supplemental funds would go not only to scientific research on implications, of the sort that Wiesner had initially advocated, but also to activities related to knowledge transfer and social implications. The new funds expanded what originally were modest ancillary activities – education, outreach, diversity, industrial affiliates, and other knowledge transfer activities, often derisively referred to as 'boxes to check off'.

In the midst of the 2002–03 media furor, these ancillary activities took on a sudden and unexpected importance. CBEN's plans for a modest conventional industrial affiliates program were greeted with a manifest lack of enthusiasm by corporations: what they wanted instead was to understand whether the public, the media, or the NGOs would accept nanotechnology; they wanted a way to 'avoid another GMO'. Far from questioning the need to study the implications, they were desperate for guidance and data on all kinds of potential implications, from basic biology to public affairs.

As executive director of CBEN, many of the ancillary duties fell to Kristen Kulinowski, a chemist who had started her career interested in education, and who had been drawn into the world of Washington science policy before returning to Rice just in time to help run the recently funded CBEN. Based on her experience in Washington DC, she decided to focus on the policy and industrial affiliates aspects of the Center, essentially by trying to figure out ways to make the research at CBEN connect to people and places outside of the Center:

> … we felt a broader conversation was more appropriate than just this bi-lateral agreement between one company and our Center. So DuPont actually wanted social science research initially. They wanted to know what factors were influencing media coverage of nano. They wanted to understand public perception, and were willing to put money into making that happen .... DuPont wanted to know where the NGOs would stand. (Kristen Kulinowski, Interview #1, hereafter KK#1)

Kulinowski came face-to-face with a bundle of issues and constituencies new to her and the Center: risk analysis, risk management, risk perception, NGOs, the media, the public, dialogue and engagement with citizens, civil society and social justice issues and so on. But what to do? How should she think about these issues as they relate to the core mission and strategies of CBEN – to develop nanotechnology for environment and health and to responsibly investigate the hazard/exposure risk of nanomaterials? Since such research was the core of CBEN's mission, it was not the case that DuPont simply wanted to fund more such research. They wanted to know something more ephemeral: How *much* research do we need, what should we do with it in order to make people feel positive about the benefits of nanotechnology, and how can we involve others in the conversation? According to Kulinowski:

> We didn't really have any model for this, we still don't see a model for this. There are industry–government consortia like the Health Effects Institute, there are organizations like Green Chemistry Institute which are academic with strong ties to NGO activists, but we didn't see

> anybody bring in like the various groups together and certainly nobody was doing this on Nano back in 2002, 2003. We had an incubation period where we thought about this. (KK#1)

The outcome of this incubation period was ICON, an offshoot of CBEN that would bring together all of the relevant groups in a forum deliberately designed to facilitate interaction and sharing of information but belonging strictly to no one. It was not clear what ICON would do, practically:

> At the early stages we were thinking about funding social science research, having a media monitor and you know doing analysis of media coverage and things that we're really not considering doing anymore. But the field was wide open because nobody was doing anything like this. (KK#1).

What 'this' was, was not clear – and remained unclear. It makes more sense perhaps to understand the statement to mean that, while everyone felt a demand, or heard a call to deal with the implications of nanotechnology, only a few people had figured out the practical, structured, goal-oriented practices that would respond to the call, and at what level. As such, ICON was faced with a seemingly infinite array of possible approaches: influencing policy, participating in standardization efforts, raising or channeling funding, consulting with corporations, monitoring the media, conducting social science research on risk and risk perception, trying to affect public opinion, and so on. What it did not do at the outset was fund or conduct research on the environmental and biological safety of nanoparticles. This was after all the 'core' research on implications that CBEN would conduct.

ICON was to include as many 'stakeholders' as possible. The term stakeholder was an obvious choice from the perspective of CBEN; it referred in general to people and groups with an interest in nanotechnology. But the term might be confusing, given its origin in corporate ethics and strategy where it was intended to differentiate shareholders from stakeholders – those people who are affected by the actions of a corporation but do not control its decisions or activities (Freeman, 1984). In the case of nanotechnology, it is not clear who the complementary 'shareholders' might be, and instead everyone was cast equally into the role of stakeholder – even and perhaps most significantly, the government (especially regulatory agencies such as the Environmental Protection Agency, the Food and Drug Administration, and the Occupational Safety and Health Administration, and standards agencies such as the American Society for Testing and Materials, the International Organization of Standards, or the National Institute of Standards and Technology). The obvious stakeholders were university scientists and engineers, primarily interested in furthering research in nanotechnology, but corporations were the most eager to join as stakeholders, especially those with active research and development projects in nanotechnology: DuPont, L'Oréal, Clorox, Intel, and Mitsubishi. Most corporations were concerned about their active research projects, but one that stood out was the Swiss Re reinsurance corporation, which was involved because of its exposure to risk as a re-insurer of corporations investing in nanotechnology. Corporations, perhaps surprisingly, were extremely eager to see 'civil society' actors involved, especially those with the power to influence public acceptance of nanotechnology.

Convincing non-corporate groups to join, however, required a great deal of effort on Kulinowski's part. Government agencies were only willing to participate as long as ICON stayed away from making any kind of policy recommendation. In contrast, NGOs and 'civil society actors' were suspicious and resistant because ICON's money came predominately in the form of gifts from corporations. The most sought-after groups, such as the ETC Group and Friends of the Earth, have never joined as a result (though they have often attended meetings as unofficial participants). The Natural Resources Defense Council participates in some workshops and on a workshop steering team. Another environmental group, Environmental Defense, has joined, along with Consumer's Union, the publisher of *Consumer Reports*, making for a somewhat odd cross-section of 'civil society.'

Corporate members in particular have seen value in the idea of a neutral forum in which these 'stakeholders' can share information. A well-dressed man from L'Oréal, for instance, made clear at the 2005 meeting in Houston that ICON served as a 'cloaking device' for many corporate and NGO members. The difficulty for someone from L'Oréal calling someone at Environmental Defense was much greater than two people calling each other simply as members of ICON. The difficulty of attracting members and the value of neutrality and 'multi-stakeholder' organization led to the creation of the governance structure of ICON, something Colvin and Kulinowski (2007) routinely mention as one of their proudest achievements. It is a structure that balances the input of each of the four stakeholder groups equally, through representatives who serve on various working groups, an editorial board, and demands that one from each group be part of any action the council takes. With the governance structure came a formal vision: to be 'a credible, international, and multi-stakeholder organization for catalyzing global activities that lead to sound and responsible risk assessment, management, and communications', and that 'works in an open and transparent manner and reaches decisions by consensus' (Colvin & Kulinowski, 2007: 8678–80).

The initially broad focus slowly narrowed to issues related to the core research of CBEN: environment and biology. In part, the field of other actors enlarged from 2004 to 2006, with the addition of three large NSF-funded Centers for Nanotechnology and Society, which took some of the pressure off ICON and CBEN to address social implications not related to safety (for example, human enhancement, social justice, or intellectual property). As a result, ICON turned to creating more specific practices that addressed environment and biology, such as creating a database of EHS-related publications, and focusing on the media representation of nanotechnology risks to environment and biology. More peripheral projects included a commissioned survey (conducted by the UC Santa Barbara NSF Center for Nanotechnology and Society) on best practices among existing corporations with respect to handling and production of nanomaterials; an EHS roadmap that would mirror the semiconductor roadmap that is so central to the semiconductor industry's self-monitoring of its progress; and various statements, both in the form of press releases and in the form of invited comments to regulatory agencies (such as comments to the EPA in summer 2007).

The database project, in particular, played an important role. It started as little more than a literature search, but as the number of relevant publications grew, it turned into an openly accessible database of more general use to ICON stakeholders and beyond. In turn it shaped what members of ICON and CBEN knew about existing research and possible new directions. In their early meetings, ICON working groups discussed the idea of turning it into a 'knowledge-base' – a term no one seemed to have a very sharp idea about, but which would allow a wide array of users to very quickly understand the significance of a given scientific study. It would be a system that organized existing research, placed it in context, commented on its relevance or reliability, and so on. Although a knowledge base never emerged, there is now a 'virtual journal' that selects a monthly set of papers from the database to highlight.

ICON also took up the practice of monitoring such research, both in academia and in corporations, styling itself as a neutral organization that could provide solid, value- and policy-neutral context to new studies or controversies. The paper by Ken Dawson and colleagues (Linse et al., 2007) mentioned at the outset of this paper was the most significant example of this kind of activity to date, involving coordination with science journalists, the creation of a 'backgrounder' by Colvin and Kulinowski, and close interaction with the journal publishing Dawson's paper (Colvin & Kulinowski, 2007). A similar experience confronted ICON in the April 2006 case of 'Magic Nano'. The German company Kleinmann produced a toilet cleaner (Magic Nano) that the Federal Institute for Risk Analysis linked to roughly 80 cases of 'respiratory distress'. Discussion within ICON centered around the kind of statement the Center would make: for some of the participants, a strong 'consumer protection'-oriented denunciation of corporations who do not carefully test and research their products was called for; for others the most galling issue was that 'Magic Nano' contained nothing qualifying as nanotechnology and expected the release to mention this. For the former, ICON's role seemed more akin to that of a watchdog-like entity, while for the latter its role was to correct misrepresentations of nanotechnology and educate consumers about the reality of the available scientific data and theory. The final document tried to do both, and ultimately lamented the lack of certainty in the case: 'This recall highlights the need for clarity with respect to terminology, hazard identification, cause and effect, and risk communication.'[3]

Icon as Membrane

The transformation of CBEN and the emergence of ICON represent the first steps towards that imaginary 'responsible institution' that Ken Dawson and Vicki Colvin found themselves discussing in Zurich – an entity that would allow scientists to go on (or perhaps go back) to 'just doing science', while ICON, or something like it, takes on responsibility; a way of responding to both a demand for responsibility that is novel and ill-understood, and a demand for pursing science as a vocation. But whatever 'just doing science' once meant, it will not be the same again for these scientists. 'Just doing science' in this context has been transformed from a set of ill-formed concerns about implications of nanotechnology and the de-funding of nanotechnology, to become something that appears to be a science of safety. Indeed, just such a controversial claim to being a new science would emerge within CBEN under the label of 'Safety by Design', a label Colvin would use to make new claims about the basic science of implications.[4]

In late 2007, when this paper was drafted, the relationship between ICON and CBEN was far more tightly coupled than it might have seemed from the outside. ICON's activities have been determined in large part by the kinds of research that can reasonably be pursued within CBEN (specifically, environmental health and safety), and in turn CBEN's research directions are influenced by what ICON can offer through its novel configuration of 'stakeholders', workshops and data/knowledge bases. ICON is thus a front end, or better, a 'membrane' for CBEN. It became the medium through which responsibility as an external demand or calling was processed, purified, or filtered into something that CBEN could imagine responding to in scientific terms. ICON's self-presentation (and the perception of many outside it) is as an institution that communicates science to the public, shaping it and making it safe for consumption, maintaining the fiction of a sharp split between science and society. But seen from inside, ICON is a mechanism that emerged out of the laboratories and offices of scientists and engineers, who were engaged in figuring out the distinction between implications and applications. It has emerged as part of making responsibility into something do-able, provable or calculable in those places where the language and tools of risks and implications seemed to fail. Where Colvin and Wiesner conducted 'fundamental research' they were already trying to figure out ways to make their research address the criticisms and concerns, not only of their immediate disciplinary colleagues, but also of their funders, administrative staff, and university leadership. With time, the scientists involved in CBEN established new forms of research that from the outside might perhaps look like merely normal development of scientific questions. But what we have shown here is that the research directions of scientists like Colvin and Wiesner, if not of all scientists, is not just contingent but also ordered by key concepts such as risk, responsibility, implications, applications, and safety. How they interpret them, and how they turn them into scientific questions, are not driven solely by curiosity or by the internal dynamics of matter, but by venues, problems and modes of veridiction in the midst of being shaped away from the labs and universities.

But what, finally, is responsibility and how is it made do-able? Our goal here has not been to characterize responsibility as such, or to explain why this vague demand exists now, but to characterize the *response* to this demand: the practical, technical, and affective orientation that the actors have adopted in order to become more responsible.[5] The language of risks dominates the discussion both inside and outside of CBEN and ICON; it is a language that structures what is possible to think and do. Speaking in terms of risks often implies a set of techniques for managing knowable uncertainty that results from practical definable actions. What CBEN and ICON confront is an uncertainty about what to make of risk now and in the future. The language of risk is only partially compatible with the vocation of science, which organizes itself around the faith that the production of knowledge is a good in itself, and therefore cannot be managed in the way that risks can. Responsibility is an alternate language – one replete with positive connotations and an important-sounding philosophical mandate – but one that is too vague to guide scientific investigation without making some sort of distinctions. As in the Weberian calling, science is a duty best met with blinkers on, such that the Good is ultimately served by piecemeal contributions of scientists without regard to value (Weber, 2004). But today, one *must* become responsible; one cannot dissent from the demand and still be considered a good scientist. However, the fact that there is a widely felt demand for science to become more responsible does not prescribe what that responsibility will eventually look like, or the effects it will have. It is nonetheless a powerful enough demand that these scientists have begun to figure out what responsibility means – to articulate solutions, or design new organizations, new experiments or new tools that address the demand as they come to understand it.[6]

One thing that is clear from our story is that responsibility must be constructed and understood as something *novel*, something scientifically interesting, and something in urgent need of funding and basic research. If it is not, then it becomes merely a 'bureaucratic' or 'downstream' problem, and thus cannot be approached as a scientific problem, the pursuit of which will bring to individuals credit, acclaim, and respect. Vicki Colvin may have started out looking for a TEM to make and study optics of materials, but what she and others found were new opportunities to make their careers. Novelty is an actant in this story; it drives actions, but is also the object of action. It is this creation of novelty that gives responsible nanotechnology a momentum and a desirability that is not simply reducible to a universal or human ethical concern that supposedly precedes the scientific project. For scientists and engineers to engage responsibility it must be novel, lest it be relegated to the relatively standardized domain of 'downstream' regulation (as in the pharmaceutical industry for example) – a domain associated with (and often undervalued) as one of public or civil service, and not one of innovation. It is also clear that the activity of defining responsible nanotechnology is coterminous with the struggle to define why nanotechnology itself is novel. The novelty of nanomaterials – the uncertainty of their scientific status in between chemistry and physics – demands *new* responsibilities, not the same old forms of audit, control, or oversight designed for eras past, whether or not they are adequate.

As scientists respond, it is in their attempts to change what they do (new research projects on toxicity or water treatment), change their organizations (creating ICON) and their goals (studying 'safety by design' not 'implications of nanoscience') in order to become more responsible, that unusual and novel things emerge in their labs, organizations, and theories. The demand to become responsible is obviously not in itself new – but neither is it eternal. Simply relying on previous solutions would be inadequate. Specifically, it would fail to maintain the openness and the moral uncertainty that allow for something other than an automatic, scripted response to take place. Responsibility is thus approached as something emergent and historically contingent, which is given stability through the practical work of creating new institutes, centers, and councils, reorganizing scientific work, and re-thinking the relationships between disciplines. The confusing cast of characters that opens our story is more than just a heterogenous collection of things that make up contemporary science. They appear on stage, or on screen, precisely because of the story of responsibility that is unfolding in settings such as CBEN and ICON. It is not pure contingency that brings them together, but a cultural and experimental engagement; an attempt to remake responsibility, remake science, and even, at the limit, remake matter.

Notes

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1. This extends beyond just the scientific fields of toxicity studies or environmental engineering as well: one of Wiesner's papers details the relative risk of different kinds of *production* processes for diverse materials, including nanoparticles (Robichaud et al., 2005). To do this, he employed some standard insurance-industry actuarial tools in order to study where along a spectrum of risk one places the processes and constituent components of nanomaterials, rather than the products themselves. No 'laboratory' research was necessary to write this paper, but it is also quite obviously not a paper on the social implications of nanotechnology. For Wiesner it is still 'basic science' in the realm of environmental science.
2. Arie Rip (2006) has provided an analysis of the 'Wow to yuck?' story as a 'folk theory' of social science that is never empirically verified. He suggests that it asserts the inevitability of nanotechnology, and the danger of a fearful public (nanophobia-phobia) without backing up these claims. 'Folk theory' in Rip's usage seems similar to Holmes and Marcus' notion of paraethnography, and captures the way powerful scientists engage in a kind of anecdote-based research that guides their understandings, but would never pass muster on their own terms as scientists (Holmes & Marcus, 2004). Rip does not note that the 'Wow to yuck?' trajectory itself engages in a complex form of argument drawn more or less directly from Leon Kass' 'Wisdom of Repugnance' paper, in which the claim is made that an immediate gut reaction should not always be dismissed in favor of rational analysis (Kass, 1997).
3. ICON Press release, 10 April 2006, 'Multi-stakeholder Council puts BfR Release on "Magic nano" in context'. Available at #60;http://cohesion.rice.edu/CentersAndInst/ICON/emplibrary/BfR%20Release%20on%20MAGIC%20NANO%20-%20web.pdf#62; (accessed 22 July 2009).
4. The story of research and its relationship to the story told here is detailed in Kelty (2009).
5. In theoretical terms, we approached responsibility as a 'problematization' to which individuals respond by creating new techniques, concepts, and practices. As it is used here, drawn proximately from Rabinow (2003), and more distantly from Foucault, a problematization is part of a series – assemblage, apparatus and problematization – each of which has its own temporality and configuration. In this story, therefore, 'safety' as it emerges within the scientific research and institutions is the assemblage, made up of particular tools, materials, labs, and people investigating the properties of materials and building models; CBEN, ICON, and the NSF are the apparatus, the infrastructural components that lend legitimacy and stability; and responsibility is the problematization, of much longer scope, stretching back to its emergence in the 19th century and developing into the 20th century notions of social and political responsibility such as those encountered in the environmental movement beginning with Carson's *Silent Spring* (1962), as well as the history of 'social responsibility' of engineers (Wisnioski, 2006). This might be one way to characterize the term in its intellectual origins, even if it does not fully explain the emergence of the concept in nanotechnology today, much less corporate social responsibility.
6. On 'figuring out' see Fortun (2009).

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Appendix

Interviews

Colvin, Vicki. Interview #1. Conducted Tuesday 1 May 2007

Colvin, Vicki. Interview #2. Conducted by Michael Lounsbury, July 2007

Kulinowski, Kristen. Interview #1. Conducted 6 February 2007

Kulinowski, Kristen. Interview #2. Conducted 27 March 2007

Wiesner, Mark. Interview #1. April 2004

Wiesner, Mark. Interview #2. 28 February 2006