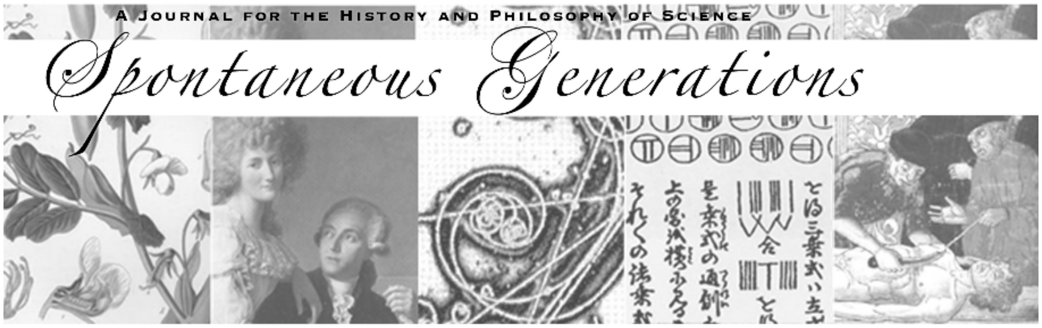

A Matter of Scale: The Visual Representation of Nanotechnologies

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A Matter of Scale
The Visual Representation of Nanotechnologies*,†

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Scale is central to understanding nanotechnologies. These technologies are usually described as the understanding and control of matter at the nanoscale, with one nanometer being 10^{-9} meter. At this scale, some materials gain new properties that can be used in the creation of new products. These properties may contribute to economic growth and social welfare but, conversely, they may also create negative effects, such as new risks to human health and the environment. As an emerging field whose consequences are still uncertain, the meanings of nanotechnologies are hotly contested.

It is generally assumed that before we can hold a meaningful discussion about the consequences of any new science or technology, we must have at least a minimum understanding of it. Around the world, discussions about nanotechnologies are therefore preceded by explanations. In this process of "science communication," visual representations play a pivotal role. Images abound in public accounts of nanotechnology. By focusing on these images, I will argue that explanations of what nanotechnology *is* do more than merely render it intelligible for a wider audience; the distinction between explaining how a certain science or technology works and debating its consequences cannot be made.[1]

This essay will highlight one particular mechanism through which seemingly neutral images are made part of the arena in which the meaning of nanotechnologies is contested. Through what I will call "scaling," juxtaposing the science or technology in question with better-known items in a particular way, science or technology becomes associated with a rich set of meanings. By illustrating some of the different ways in which scales are made operational

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1 See B. Wynne, Public understanding of science, in *Handbook of Science and Technology Studies,* eds. Sheila Jasanoff, Gerald E. Markle, James C. Petersen, and Trevor Pinch, 361-88, (London: Sage, 1995); and B. Wynne, Daring to imagine. *Seminar*, 597(5) (May 2009): 25-32. www.india-seminar.com/2009/597/597_brian_wynne.htm .

in visual representations of nanotechnologies, this essay aims to contribute to a better understanding of the ways in which these meanings are contested visually.

I. The Nano-scale

The nanoscale is at the heart of the definition of nanotechnologies. For instance, the influential American National Nanotechnology Initiative (NNI) defines nanotechnologies as "the understanding and control of matter at the nanoscale" (2012) and the British Royal Society (BRS), together with the Royal Academy of Engineering (RAE), note that "the only feature common to the diverse activities characterized as 'nanotechnology' is the tiny dimensions at which they operate" (2004, vii). Although the terms "scale" and "size" are often used interchangeably, the concept of scale most aptly captures what nanotechnologies are all about. Whereas "size" stands for the two- or three-dimensional length of an object, "scale" refers to the size of an object relative to other possible sizes. The novelty of nanotechnologies is the fact that materials with the size of nanometers behave differently *as relative to* the same materials of different or larger sizes.

In the most basic sense, the nanoscale is defined in relation to set of standards established by the International System of Units (SI), also known as the metric system. The prefix "nano" (from the Greek word for dwarf) has been used in the metric system since 1960 and refers to a billionth of a meter. Accordingly, the nanometer exists as a size relative to the meter.

The metric system is intended to provide universal definitions of size and scale. These definitions do not refer to any particular objects nor are they solely applicable to certain objects. Yet even this highly abstract definition of the nanoscale cannot be understood in isolation from its societal function. The chief incentive for the establishment of the metric system was the need for uniform measurement standards in the exchange of goods. It allows two parties in an exchange to compare the price of a certain quantity more easily. This is reflected in the definition of the meter. The most recent amendment to this definition was made in order to simplify measurement in light of existing measurement technologies. Even in its most abstract sense, the notion of the nanoscale is a construction that was agreed upon in order to serve certain societal objectives, in this case the expansion of trade.

The technical definitions of nanotechnologies that refer to the nanoscale do not carry a set of associations that is rich enough to allow for discussion of its societal consequences. For instance, when conceptualizing nanotechnologies within the vocabulary of the metric system, one would define nanotechnologies as any technology between the range of a billionth and ten-millionth the size of the distance travelled by light in a vacuum in 1/299792458 of a second, with the second being defined as the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom, in rest at a temperature of 0 Kelvin. One can readily see that explaining nanotechnologies using such technical definitions does not provide fertile ground for public debate. Yet, as Cynthia Selin (2007) has aptly noted, the abstract and technical nature of these scale-bound definitions has not prevented the proliferation of wild visions. The meanings that are attributed to nanotechnology range from nano-utopias in which nanotechnology provides the engine for a new industrial revolution, to nano-nightmares which portray nanotechnology as a force that threatens to destroy the planet (McGrail 2010). As will be illustrated in the next section, one important mechanism through which seemingly abstract nanotechnologies became the object of debate was "scaling."

II. Scale and Visual Representations

In the metric system, the nanoscale is standardized in order to facilitate the exchange of goods across geographical boundaries where previously different systems of measurement were used. Scale can also be made operational to align nanotechnology to other societal objectives. But whereas the metric system standardizes the nanoscale in order to restrict its meaning, visual representations of nanotechnologies often diversify its meaning.

The use of visual scales has proliferated in accounts of nanotechnology with dozens of different scales being created around the world. As Latour (1986, 19) has observed, "no matter what the (reconstructed) size of the phenomena, they all end up being studied only when they reach the same average size. Billions of galaxies are never bigger, when they are counted, than nanometer-sized chromosomes." Visual scales make use of this practice to explain nanotechnology by juxtaposing items at the nanoscale to a number of differently-sized items that are better known. The difference in size between at least two well-known items, whose size is easily grasped, is then related to the size of the nanotechnology object. This juxtaposition creates an impression of the scale that defines nanotechnologies.

What constitutes a "well-known item" depends on the audience. This partly accounts for the large number of scales around the world (since a scale used in one place does not automatically resonate in another) and is also a source for the diversity of meanings that are attributed to nanotechnologies in the process of scaling. For instance, in South Africa, host of the 2010 FIFA World Cup soccer, nanotechnology is regularly explained by reference to soccer. In Figure 1, used in a presentation in South Africa, nanotechnology is explained by depicting the size of a soccer ball in relation to the earth as similar to the size of a nanoparticle in relation to a soccer ball. The scale is used to provide a reference point for imagining the otherwise abstract small size of nanotechnologies. The scale relates the difference between an item that can be directly observed and a well-known object of immense size to the difference between the directly observable item and the new, unknown items at the nanoscale. As such, it successfully provides the audience with some sense of what nanotechnology is.

But there is more to the image than merely explaining what nanotechnology is. Scaling nanotechnologies with soccer balls and the earth allows particular associations to enter the discussion. Primary amongst these is the association of play. Even though the image was used in a presentation about the potential toxic effects of nanotechnologies to human health and the environment, the soccer ball and the human figure convey an image of joyfulness and play.[2] The bright colors and the enthusiastic caption ("VIVA!") leave no doubt about the positive nature of the association. Furthermore, the reference to the World Cup in South Africa, when the world's eyes were directed to that country, mobilizes a speculative future in which South African nanotechnology is put at center stage as well. This is reinforced by prominently marking South Africa on the earth with a red star. The repeated articulation of nanotechnologies in reference to a soccer ball illustrates the persistence of this particular operation of scale, at least in South Africa.[3]

However, when one takes a closer look at the scaling activities of actors critical to nanotechnologies, it becomes clear that the pendulum of positive and negative associations can also swing either way. For instance, the Action Group on Erosion, Technology and Concentration (ETC Group) has been very active in addressing the risk of nanotechnologies. First published in 2003 (ETC Group 2003) and reprinted in later reports (ETC Group 2004; ETC Group 2005), their reports prominently feature a scale that also relates the size of well-known items to items at the nanoscale (Figure 2). Consisting of five steps, it relates items of different sizes to a man in a suit. This image translates the size of all items into nanometers. For example, the image shows that the man's fingertip is 18,000,000 nanometers, his hair is 80,000 nanometers wide, a virus is 50 nanometers and an atom is 0.15 nanometer. Whereas the previous scale gave a sense of the nanoscale by relating nanoparticles to a large item like the earth, here a sense of the small size of nanotechnologies is given by translating the size of the man, the finger, and the human hair into nanometers, yielding

[2] This association of nanotechnologies with play has a strong tradition that has been well documented by C. Milburn, Just for fun: the playful image of nanotechnology, *Nanoethics* 5(2) (2011): 223-32.

[3] For examples, see the following South African accounts: M. Scriba, *Nanoscience and Nanotechnology*, 2008, www.frayintermedia.com/download/sci_conf/Nano%20-%20SAASTA %202008%2011.pdf; National Institute for Occupational Health (NIOH), *Nanotechnology*, 2011, www.nioh.ac.za/?page=nanotechnology&id=76; and N. Musee, *Development of National Nanotechnology Risk Assessment Research Platform: Fundamental Building Blocks*, 2006, www.csir.co.za/nre/pollution_and_waste/pdfs/Musee_Development%20of%20National.PDF.

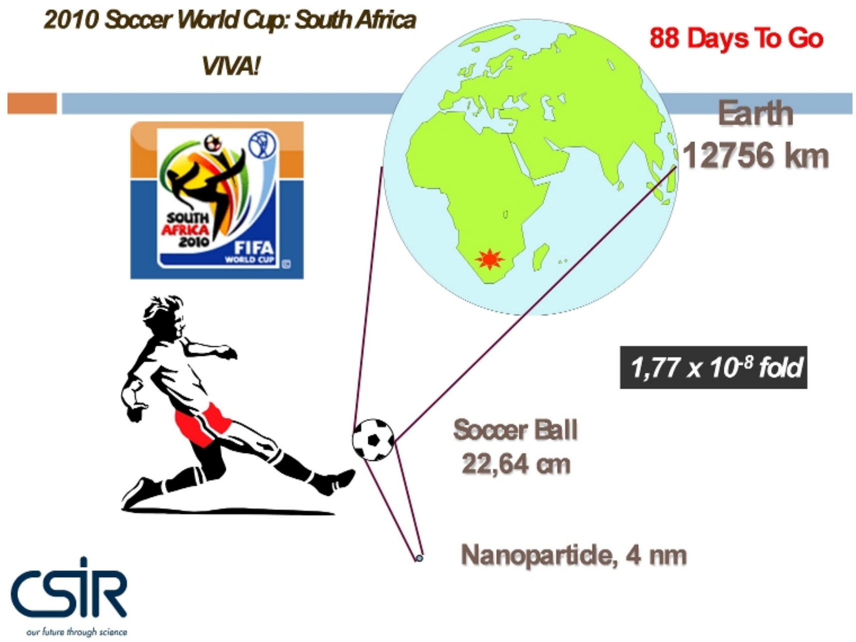

Figure 1. Ndeke Musee. A South African scale (2009).

enormous numbers. Subtly, the only item located at the nanoscale is a virus—an undesirable object, particularly when situated in the context of a report that identifies nanotechnologies as a potential threat to human health.

The creators of these two scales held explicit opinions about the (un)desirability of nanotechnologies. Whereas the ETC Group aims to draw attention to the potential risks of the technology, the South African scale portrays nanotechnology as an opportunity for South Africa in a global landscape. However, the intention of the designer is not necessarily relevant in scaling nanotechnologies; these scales *cannot help* but do more than merely explain nanotechnology.

Take for instance the so-called "nanozoomer" used in a societal debate on nanotechnology that was held in the Netherlands in 2009 and 2010 (Figure 3). These images were shown on a website that provided information about nanotechnologies.[4] The objective of this scale was explicitly not to take a stand, but merely to inform the public that could then form an opinion about the consequences of nanotechnology. The scale takes a somewhat different form. Using the scalar slope of the metric system, the zoomer would show one image at a time. At each mouse-click on the image a new image appears that descends one scale down, ending with the nanoscale (with the exception of the decimeter and the millimeter). While the various images are never spatially juxtaposed,

[4] I retrieved the illustration on August 9, 2010; unfortunately, it no longer appears to be accessible.

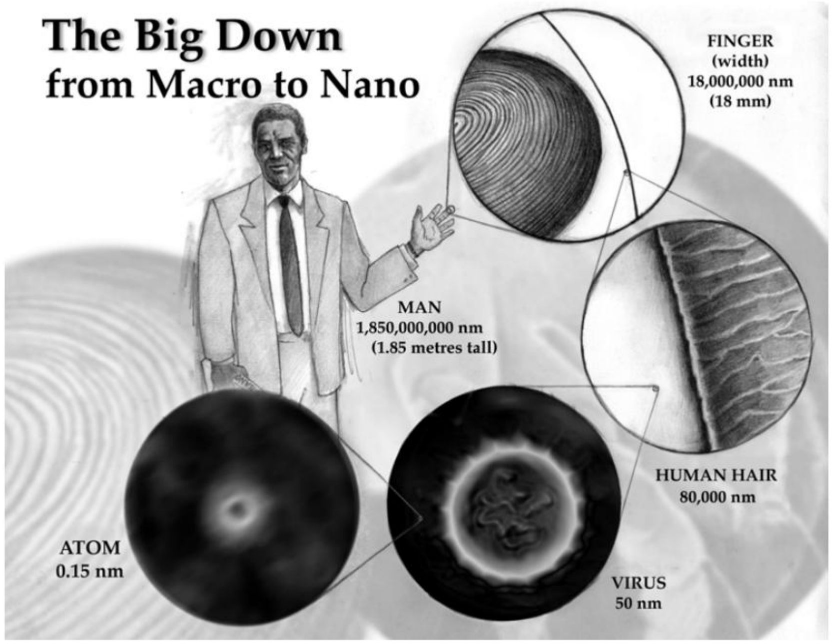

Figure 2. ETC Group. A scale used by the ETC Group (2003).

the large number of mouse-clicks required to arrive at the nanoscale gives an impression of its smallness.

The first image shows a one-meter tall child. The accompanying text of each of the other images refers back to it. For instance, the second image shows his hand and notes "the tip of his little finger has a length of one centimeter." The choice of the first image is instructive; the child represents both innocence and vulnerability, but he stands confidently. Once we arrive at the nanoscale, as in the scale of the ETC Group, an image of a virus ("that gives him a cold") is shown as a reference point for the size of one hundred nanometers. But whereas the virus is the only image at the nanoscale depicted by the ETC Group, the next step of the nanozoomer immediately provides a more positive counterexample by depicting "antibodies that protect him" from the virus. Whereas illness may be situated at the nanoscale, so is the solution to that problem: a positive association is created and in fact strengthened by the final image that exclaims "the sugar molecule that gives him energy is one nanometer!"

A final example provides a more critical reflection on scaling. As part of the same Dutch societal dialogue, several artists were invited to reflect on nanotechnologies. An explicit aim of this project was to contribute to creating "a fuller and richer understanding of possible societal meanings of innovations from nanoresearch" (Hanssen 2010). One of the artists, Merijn Bolink, started with a pair of candlesticks. Using an electron microscope (an item regularly used in nanotechnological practice), Bolink created a very small image in the

Figure 3. Publimarket The Hague. The various images of the nanozoomer (2010).

shape of the original candleholder, consisting entirely of one of the original candleholders.[5] He divided the other candlestick in 144 pieces and sent them around the world. When projected on a world map, the receiving addresses together formed an enormous candleholder measuring 2000 by 6000 kilometers (Bolink 2011). The artist often makes sculptures consisting of their own material. We can view the chandeliers as a metaphor for nanotechnology. Both new candleholders consist entirely of materials from the original candleholders. Yet they are transformed into something new, much the same way nanotechnology makes use of the new properties that materials gain once they are manifest at the nanoscale.

Figure 4. Left shows the microscopic image of a candlestick. The central image shows the original candleholders, the left one having been cut up into 144 pieces. The right image shows the candlestick that appears when all the addresses to which these pieces have been sent.

Although Bolink was initially afraid that in making nano-art, "the phenomenon of scale could very easily overrule all other layers of content in the work" (Bolink 2010, 15), the result takes scale as a focus but manages to add several layers of meaning. The artist repeatedly insists the work is invisible and can merely be imagined, yet accounts of the works of art are invariably

[5] Bolink (2010) calls his work "nano art" and the aim of his project is to bring nanotechnologies to the attention of the public. Yet note that although he refers to the small chandelier as the "nanochandelier," the candleholder is not really nano-sized (according to the often-used definition of nanotechnology being between 1-100 nanometers). In fact, it is about 900 x 2500 nanometers.

accompanied by images showing both the candlestick at the nanoscale and a world map in which the locations of the divided candlestick are highlighted (Figure 4). This scaling activity thus takes a similar form to that of the soccer balls discussed above, relating an everyday object to both larger and smaller scales. Yet whereas proportionality was central in the soccer example, Bolink is more concerned with the combination of invisibility and creation, shared by the large and the small candleholder. "Both the nano and the giant candlestick are part of the physical world, consist of atoms, have dimensions and a place in time, but they remain invisible to us, unless they are mentally constructed" (Bolink 2010, 17). One could even interpret the artwork as a parody of regular scaling exercises in explaining nanotechnology. By emphasizing the inherent invisibility of material at the nanoscale while simultaneously stressing its existence, the work suggests a blurring of the boundary between mind and matter, making nanotechnology, unlike other scales, into a category of objects that cannot so easily be compared to regular objects in our everyday life (Doorenbos 2011, 44).

III. Conclusion

From the cover of *Nature* to the business sections of newspapers, and from online galleries to conference papers, images of nanotechnologies are circulated widely, rarely going unnoticed. Focusing on these visual representations of science and technology provides a valuable lens through which to investigate how technologies are embedded in society.

In particular, as we have seen, scales are a popular mode of visualizing nanotechnologies. These scales explain nanotechnology by juxtaposing the unknown technologies at the nanoscale to better-known objects of larger scales. There are various ways of scaling, for instance, through juxtaposing images of items with various sizes in accordance with the steps in the metric scale (as we saw in the nanozoomer) or by depicting various items with reference to their size in nanometers (as we saw in the scale of the ETC Group). That these objects are directly accessible to human experience is no precondition for successfully scaling nanotechnologies. For instance, the South African scale relates nanotechnology to the size of the planet. While it is very hard to perceive the size of the earth directly (the candleholder scale of Bolink cleverly plays with this invisibility), this object is sufficiently well-known to provide a rich source of meaning. Scales thus translate an abstract object outside the range of everyday understanding into graspable proportions. As such, these images render nanotechnologies suitable for wider dissemination.

Yet scaling not only renders the abstract realm of science intelligible; it also makes a first step both in imagining the potential consequences of the technology and in judging the desirability of those consequences. Whereas the *effect* of relating nanotechnology to other technologies and items has occasionally been observed, the precise mechanisms behind these juxtapositions have remained unarticulated. This article has provided a first step in thinking about those mechanisms by arguing that through scaling, seemingly neutral images are made part of the arena in which the meaning of nanotechnologies is contested. Very much like the use of metaphors, in juxtaposing nanotechnologies to items that are better known, images suggest a direct mapping of the meanings associated with those well-known objects on the unknown nanotechnologies. Although all these scales seem to put the size of the items up front, associations of play, risk, and invisibility can be inserted by scaling nanotechnology, along with references to the health of children and even the position of one's country in the world. Explaining nanotechnology through these scales brings various potential societal consequences into view (such as harmful effects to human health or the global position of South Africa) that are hard to imagine when nanotechnologies are explained using technical definitions. Each association suggests different societal consequences, inviting particular interpretations and story-lines while excluding others, thus framing the debate rather than merely explaining what the technology is.

Scale is intimately bound up with nanotechnology because this technology is itself defined on the basis of scale. Yet scaling also occurs in other fields that deal with items invisible to the naked eye: astronomy, chemistry and biological sciences all make use of scales to attribute meaning to the phenomena under study. Natural phenomena outside the realm of human sensory capacities, like nanotechnology, need to be translated into an intelligible and communicable format. One way in which this happens is by using a particular scale to describe them that connects the phenomena or technology to everyday life. By associating objects at the nanoscale with images of other sizes, the images 'scale-up' the imaginative possibilities of the potential consequences of these invisible and future technologies.

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References

Bolink, Merijn. 2010. Transcendente nanokandelaars. In *The Phenomenon of Scale. The Art of Nanotechnology*, Qua Art-Qua Science, 14-25. www.quaartquascience.nl/ fileadmin/user_upload/documents/ Uitgaven/Nov_2010_NANO.pdf.

Bolink, Merijn. 2011. *The Phenomenon of Scale*. merijnbolink.blogspot.com/search/label/ publications.

The British Royal Society and The Royal Academy of Engineering (BRS and RAE). 2004. *Nanoscience and Nanotechnologies: Opportunities and Uncertainties*. Cardiff: Clyvedon Press. www.nanotec.org.uk/report/Nano%20report%202004% 20fin.pdf.

Doorenbos, Claartje. 2011. Atomaire kandelaar: Even verbonden met het universum. *Flux* 4 (January): 44. www.rathenau.nl/uploads/tx_tferathenau/Flux_4- Rathenau_Instituut.pdf.

Erosion, Technology and Concentration Group (ETC Group). 2003. *The Big Down. Atomtech: Technologies Converging at the Nano-scale*. www.etcgroup.org/upload/ publication/171/01/thebigdown.pdf.

Erosion, Technology and Concentration Group (ETC Group). 2004. *The Little Big Down: A Small Introduction to Nano-scale Technologies*. (June). www.etcgroup.org/sites/www.etcgroup.org/files/ publication/104/01/ littlebigdown.pdf.

Erosion, Technology and Concentration Group (ETC Group). 2005. *A Tiny Primer on Nano-scale Technologies and "The Little Bang Theory"*. www.etcgroup.org/upload/publication/55/01/tinyprimer_english.pdf.

Hanssen, Lucien. 2010. Looking at the unseeable. In *The Phenomenon of Scale. The Art of Nanotechnology*, Qua Art-Qua Science, 6-13. www.quaartquascience.nl/fileadmin/user_upload/documents/ Uitgaven/Nov_2010_NANO.pdf.

Latour, Bruno. 1986. Visualisation and cognition: drawing things together. In *Knowledge and Society Studies in the Sociology of Culture Past and Present*, ed. Henrika Kuklich, 1-40. Greenwich, CT: Jai Press.

McGrail, Stephen. 2010. Nano dreams and nightmares: emerging technoscience and the framing and (re)interpreting of the future, present and past. *Journal of Future Studies* 14(4) (June): 23-48.

Musee, Ndeke. 2009. *Nanotechnologies risk assessment: a perspective from developing countries*. Presentation given at the 7th congress of toxicology in developing countries. Sun City, South Africa, 6-10 September, 2009. www.saicm.org/documents/OEWG/Inputs% 20on% 20Nano% 20report/ South% 20Africa_Nanotechnologies% 20risk% 20assessment% 20a% 20 perspective% 20from% 20the% 20developing% 20countr.PDF.

National Nanotechnology Initiative (NNI). 2012. *Nano.gov. National Nanotechnology Initiative*. www.nano.gov.

Publimarket, The Hague. 2010. *Nanozoomer.* www.nanopodium.nl/wat-is-nanotechnologie/.

Selin, Cynthia. 2007. Expectations and the emergence of nanotechnology. *Science, Technology, and Human Values* 32(2) (March): 196-220.