Collapsing Scale: Nanotechnology and Geoengineering as Speculative Media

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Abstract. One of the central discursive mechanisms by which nanotechnology and geoengineering proceed in their narrative and concrete medial modes is one of "scalar collapse." This is the process by which objects occupying two or more different scales are articulated together and made commensurate so that the difference between them is elided. This discursive and medial process is best understood as a form of production that generates both ideational and material forms (ideas, ideologies, devices, materials). This chapter analyzes the popular Hollywood film *Fantastic Voyage*, images produced by atomic force microscopy, the early modern utopian imaginings of Francis Bacon, the neoliberal rationality of Bjørn Lomborg's geoengineering advocacy, and a prominent geoengineering proposal to blanket the atmosphere with levitating nanoscale discs. In all of these cases the human individual, made speculatively contiguous and commensurate with the atom and the planet, occupies a privileged scalar position in danger of eliding significant differences of scale and complexity, and thereby limiting the potential for scientists and laypeople alike to engage objects at nano- and geo-scales in more generative, ecologically sustainable, and creative ways.

Keywords. Nanotechnology, geoengineering, speculatorship, *Fantastic Voyage,* scalar collapse, scalar bias

Introduction

Nanotechnology and geoengineering, as sets of actual procedures and assemblages of speculative imaginings, seemingly address phenomena at scales radically alien to those of both the human and each other. I will argue in this chapter, however, that both nanotechnology and geoengineering function according to the same abstract *diagram*, or model of speculative production.[1] When we focus on nanotechnology and geoengineering as cultural discourses (bracketing out for the moment their sociological effects and technological products), we will bring into view not only their structural similarity,

[1] I adapt this notion of the diagram from Giles Deleuze and Felix Guattari, who introduce the concept as a form of the virtual. For them, the "diagram" or "abstract machine" of an assemblage describes its potential functions or possibility space. A diagram is abstract in that the set of operations, or relationships between components, is independent of any particular material instantiation, but nevertheless immanent to any of its instantiations. Thus unlike a pictorial engineering diagram, which describes and circumscribes a particular form, a proper abstract diagram is a philosophical entity that describes the possible configurations and transformations open to an assemblage. For Manuel DeLanda, the Deleuzean concept of the diagram can be traced back to Deleuze's concepts of difference and virtuality. The diagram is virtuality itself, understood as innovation and open potential rather than deterministically describable configurations or states. See Gilles Deleuze and Félix Guattari (1987, 141-142) and Manuel De Landa (2000).

but also their joint reliance on an unacknowledged scalar bias that articulates both sets of practices to an implicitly normative scale: that of the human perceptual apparatus. By tracing several contemporary and historical examples of nano- and geo-rhetoric, from *Fantastic Voyage* to a proposal for planetary-wide deployment of self-levitating nano-particles, I will begin to sketch a cultural genealogy of their shared speculative imaginings. Additionally, by suggesting that a common discursive mechanism of "scalar collapse" is at work through this genealogy, I hope to open a dialog about potentially more generative, less anthropocentric ways to approach the nanoscale and the planetary scale in our speculative encounters.

The "speculative media" in the title of this chapter are the outputs of these discursive practices, the cultural objects produced by nanoscientists, journalists, and Hollywood filmmakers alike: scientific publications, popular science writings, images rendered through nanomicroscopy, the diagrams produced by geoengineers, and the films and other media that draw upon and produce the cultural imaginaries of nano and geo. What all of these medial objects have in common is that they contain, embedded within them, formulations of alternate worlds or possible futures. Additionally, nano- and geo-discourse relies upon a set of (usually unacknowledged) scalar assumptions. What I refer to as "scalar collapse" is a discursive process by which two or more different scales are articulated together and made commensurate so that the difference between them is elided. I argue that both nano and geo discourses function by engineering a form of scalar collapse that figure nano-worlds and the planetary milieu in terms of human futures rather than as autonomous environments at other scales. As cultural practices, both discourses are forms of production, harnessing scalar collapse to produce both ideational and material forms: ideas, ideologies, devices, and materials.

1. The Transcalar Voyage

Colin Milburn has called the speculative dimension of nanotechnology "nanovision," or a type of seeing that is both science and science fiction, a future-oriented fabulation that produces a very real form of post- or trans-humanism. For Milburn, this process is primarily discursive, a looking into or speculating about a future that hasn't happened and may never happen, but whose fabulation modifies the present (Milburn 2008). What I wish to emphasize is that nanotechnology, in both public and specialized discourses, is a form of *production*: it generates concepts, percepts, and material goods. K. Eric Drexler's effusive book of nano-futurism is titled *Engines of Creation* (Drexler 1986). This title is particularly *apropos* because nanotechnology, as cultural practice, is a kind of machine for turning inputs into outputs: an engine. Like any engine, it harnesses a differential in order to drive change. In this case, the conceptual machine of nanotechnology harnesses a scalar differential as its gradient of production.

Let's explore this process via an example that captures the abstract diagram of nanotechnological production nicely: the 1966 film, *Fantastic Voyage.* In beginning with an example that predates the institutionalized practice of nanotechnology as well as the popularization of the term in the broader culture, I hope to isolate some of the film's relevant diagrammatic features. My purpose here is not to assess the film's subsequent socio-historical impact on the general public or nanoscientists, but rather to close read it as a paradigmatic formulation of the dynamics of scalar collapse, which I argue subtend the representational logics of nanotech and geoengineering media.

Fantastic Voyage harnesses a basic scalar differential for mainstream entertainment: the gulf between the scale of the macroscopic human body and the scale of its microscopic constitutive cells. Narratively, the film charts the "voyage" of a group of scientists along two axes: a scalar axis (they and their submarine shrink to the size of a single cell) and a spatial axis whose progress is marked by the anatomy of the human body (Destination: Brain!) (*Fantastic Voyage* 1966). These axes define the coordinates of the milieu through which the scientific team must travel. Here the alien "environment" is a normal-size human body, while the "explorers" are miniaturized humans. Despite these narrative tropes of miniaturization and exploration, the film's aesthetics (and underlying model of physics) reverse the narrative's scalar relationship between explorers and environment by presenting a *mise en scène* dominated by normal-scale human bodies (the actors) placed within constructed sets that aesthetically resemble copious quantities of fabric-like tissue and mucous-like surfaces. This is not merely a question of the material limitations of filmmaking constraining the scalar conceit of the narrative. As the original theatrical trailer for the film makes clear, these countervailing aesthetics are framed by the studio (20th Century–Fox, which both produced and distributed the film) as fundamental to the consumer's experience of the film itself.

The trailer for *Fantastic Voyage* directly addresses the viewer in both its spoken narration and textual intertitles, vowing to "[drop] the bottom out of the world you know and understand" (20th Century–Fox 1966). This promise of epistemic vertigo is articulated to the technological affordances of the film camera, which is mentioned three times in this two and a half minute trailer: "New on the screen . . . you are going where no man or camera has ventured before." The camera, which produces the images that constitute the film's novelty and aesthetic pleasure, is itself figured as an actor in a drama of production that collides with the diegetic milieu of the film's narrative. "Four men and a beautiful girl, off on a fantastic voyage, actually entering inside the human body . . . You are there with them, sharing a breakthrough in motion pictures." The euphoria of entering the human body becomes a collective experience that the audience can somehow share with the diegetic characters, who themselves apparently partake of the pleasure in experiencing the non-diegetic novelty of the film's apparatus of production. Thus the collapse of scales here, the visual articulation of human bodies *inside* a human body, is figured by the film's trailer as further collapsing the distinction between the fictional world evoked by the film and the "real" world of the film spectator. The porousness of the human body is figured as a scalar porousness, afforded by cinematic production itself.

"When you come out, you may never look at yourself in the same way again," warns/promises the trailer, further suggesting that the subject matter of the film is the viewer of the film, or more precisely, the scalar relationship between the Cartesian ego and the mechanistic vessel of the human body. At the end of the self-reflexive experience of filmmaking that is *Fantastic Voyage*, the viewing subject will have encountered herself in new ways, othered herself through the productive scalar transformations of the cinematic medium. This form of production is at once narrative, economic, and material: as producing engine, *Fantastic Voyage*'s outputs include props, sets, the photographed representation of these objects, the assignation of value to the medial experience of the film, and of course, the commodity of the film itself.

This engine of production is driven by a collision between two scales that are actually rendered commensurable, and thus seeable, by and through the medium of film. Aesthetically, *Fantastic Voyage* rehearses a transcalar encounter, or the collision of objects at one nominal scale (that of the filmic spectator's body) with another (the

microscopic tissues and fluids of the human body's interior). The spectacle of the film, captured by the adventurous camera, is this encounter between the whole human body and its tissues. The film (and the process of filmmaking) represents the speculative erasure of scalar difference. Raquel Welch and the other actors directly interact with larger-than-life blood and tissue cells (to their peril) as if they were walls, tunnels, and macroscopic predators. The filmic apparatus speculatively collides these scales by photographing them in the same frame.

While the narrative conceit of the film relies upon a trope of miniaturization, of entry into a foreign landscape, the scalar relationship between the viewer and the actors is held constant by the self-reflexive conceit of the camera. Not only on the film set, but in the speculative milieu produced through the experience of the film as commodity, the operative scaling vector is *enlargement*. The spectator, camera, and actor remain scale-fixed, while the speculative milieu of the human body is enlarged into a macro-landscape. The collapsing of these two scales in the visual economy of the film thus narratively highlights the environment being explored even while privileging the scale of the observer. Ultimately, the film is not about experiencing the inside of the human body at its native scale, but rather experiencing the enlargement of the human body until it becomes potential milieu at the viewer's scale through the speculative apparatus of film spectatorship. Somewhat less awkwardly and more whimsically, I will call this phenomenon *speculatorship*. This term designates the production of an experienced virtual alterity through the mediated encounter between a spectator and a speculative milieu. *Fantastic Voyage* and its trailer represent a particularly interesting instance of speculatorship in that they place the viewer in a potentially alienating relationship with a milieu that is actually a scaled-up version of the human body itself, while simultaneously scale-suturing her to the subjective experience of the characters, thereby eliding the scalar difference between the microscopic and the macroscopic.[2]

Even though *Fantastic Voyage* is not ostensibly about nanotechnology, it articulates a set of scaling procedures that describe the basic abstract diagram of much nanotech and geoengineering discourse: two scales are collapsed through technological mediation, narratively highlighting the subject's experience of the "other" scale, while actually figuring that other scale as a product of and for the consumption of the scale-fixed observer. While in one sense these processes of production claim to be exploring the difference between two scales, and do indeed harness that difference, they do so only in a process of making equivalent, making commensurable.

2. Nano-Microscopy as Scalar Collapse

In any encounter between two scales, one is always privileged. No laboratory practice better exemplifies this maxim than atomic force microscopy. The term "microscope" itself suggests that this ubiquitous device (the AFM) is, in its functional affordances, on a scalar continuum with the classic optical microscope. While the optical microscope allows us to see microscale objects (through a process of optical magnification), probe microscopes such as the scanning tunneling microscope (STM) and atomic force mi-

[2] In film theory and criticism, "suture" refers to the process by which the viewer is tied to the fictional world of the film and thus constituted as a subject through a process of identification. This has the effect of naturalizing the film's discourse, hiding the conditions of its own construction by capturing the viewer at the level of fiction (Dayan 1974).

croscope (AFM) allow us to sense or "touch" atomic-scale objects (through a process of digital scaling). Gimzewski and Vesna see the shift from optical to probe microscopy as "a major paradigm shift—rather than using lenses and waves, they were recording by feeling" (Gimzewski and Vesna 2003, 14). An AFM produces, though a series of complex analog and digital mediations, a computer-rendered image reconstructed from the raw data of the scan and built-in models of atoms and molecules. The final result, an image on a monitor, appears at first to be a magnified version of the surface being scanned. It is a commonplace among nanoresearchers and scholars that these visualizations are not "natural" renderings of what the nanoscale "really" looks like. They are only produced when raw data is combined and re-shaped by models of nanoscale behavior and structuration, and additional human input for an array of arbitrary parameters, such as false color, the relative height of individual molecules, and so forth.[3] As Bensaude-Vincent and colleagues explain with respect to the relationship between theory and observation, "These simulations use models that are calibrated to make theories fit with the experiment. They do not test theories. Rather, they simulate the interpretation of theories in a back-and-forth process with the experiment, until the two present a sufficiently satisfactory likeness" (Bensaude-Vincent et al. 2011, 379). These authors suggest that this back and forth is emblematic of technoscience, which is concerned not with confirming or disconfirming hypotheses, but rather with establishing "novel properties that might be functionalized in certain ways . . . and it seeks to master complexity and to control processes and phenomena" (366).

The probing of these properties and the establishing of circuits of control do not require or afford magnification. If we take "magnification" to mean "the apparent enlargement of an object as seen through a lens, optical instrument, etc" (Oxford English Dictionary), it is clear that nano-microscopy achieves its visualizations through other means than the bending of light to produce an "apparent enlargement" of an object that is actually smaller than its representation. Specifically, nano-microscopy *produces* the nanoworld within the human-scale milieu. As Sacha Loeve explains, this is less a question of representation than it is of conjoined processes of interaction: "It is as if you were within the sample, on the surface, with the molecule as an Ampere-meter, except that one electrode is at the nanoscale and the other at the macroscale" (Loeve 2011, 210). Thus two scales are collided, not as an optical trick that confuses the brain, but as a conceptual enlargement. Features of the nanoscale interact with features of the macroscale through a transcalar interface via a series of amplifications (of voltage differentials, lever movements, etc.) discursively tied to ideal models of molecular behavior and structure that together produce a set of images that describe and produce the site of interaction. In the same fashion as the filmic apparatus in *Fantastic Voyage*, probe microscopy is a form of scalar media that conceptually enlarges a target domain and places the scale-fixed observer into it. The result is a collapse of scalar difference. Thus for nano-researchers as well as consumers of popular nanotech media, STM and AFM labwork is a form of speculatorship as defined above.

Because STMs and AFMs image surfaces rather than organisms or objects (though all of these are discursive, rather than ontological, categories), nano-microscopy as a

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[3] Nonetheless, communities of nano-researchers have, over time, formed a relatively stable set of tacit rules to determine which sorts of visualizations are "accurate" and which are manipulative (Ruivenkamp and Rip 2010). Even so, as Ruivenkamp and Rip argue, all nano-imagery (that produced through microscopy software as well as that produced by commissioned artists) is understood by nano-researchers and journalists to have a didactic or rhetorical component. That is, such imagistic production is tacitly understood to be "impression management" (Ruivenkamp and Rip 2012, 13).

media landscape primarily produces images of what we ordinarily think of as *space*. Topological ranges, landscapes, formations . . . These spaces are rendered by measuring topological differentials on surfaces that appear relatively homogeneous or smooth when experienced by the human sensorium, as samples large enough to be visually resolved by humans. These surfaces, when explored at the nanoscale, reveal new topological anomalies that seem, like fractals, to reproduce forms homologous to macroscale landscapes. Rendered in bright, false-color imagery, nano-surfaces can be made to look strikingly like topographic maps that function to "reveal" features of macroscale landscapes such as mountain ranges, the sea floor, and so forth.

Especially in the 1990s, these "topo" nano-maps were popular visualizations of speculative nano-ecologies. By representing nanoscale ecology as topographically familiar (and thus discursively habitable) landscapes, these images collapse scalar difference, allowing the human-scale observer to project the qualities of macroscale landscape onto her engagement (conceptual or material) with the nanoscale. As Milburn has noted, the production of these images represent an "effort to contain novel territory within a representational topography that is pictorial, rhetorical, and numerical all at the same time" (Milburn 2008, 65-66). Some recent nano-imagery, such as the striking "Innerspace" series by Michael Oliveri, has tended to favor photo-realism, a reduced color palette (Oliveri's images are rendered in black and white), and lower angle perspective in order to emulate the atmospheric landscapes of art photography or science fiction films. Oliveri's images use photographic techniques such as reduced depth of field, horizon lines, and added textures to emulate the aesthetics of landscape photography (Oliveri 2010). Images such as these are no longer maps, or medial representations of landscapes plotable and colonizable as open space, but evoke the landscapes themselves. Nonetheless, these landscapes, in becoming photo-realistic, become all the more alien.[4] That is, the more recognizable they are as tropologically landscaped, the less Earthly they seem. As other-worldly landscapes, they evoke the narrative trope of space exploration and colonization. These are the sorts of images conjured up by science fiction films set on distant planets, or NASA probes sent to outlying planets and their moons in our own solar system.

In 2008 NASA produced and circulated an extraordinary image that crystallizes the relationship between scalar collapse, space exploration, and nano-microscopy as production apparatus. That year the agency's Mars Phoenix Lander touched down on Mars' southern polar ice cap. Its onboard instrumentation included an AFM, which promptly began imaging Martian soil samples deposited on its sample surface by its robotic arm. Researchers at NASA then composited together two images produced by the lander: a photograph from its onboard optical microscope and an image generated from its AFM (figure 1).

[4] Oliveri's images were produced by imaging samples of zinc oxide that have been heated to 500 to 600 degrees Celsius by University of Georgia materials scientist Zhengwei Pan. The metal vaporizes and then cools, causing the vaporized particles to form bizarre and intricate shapes that settle into their own topographies; see Patowary 2009.

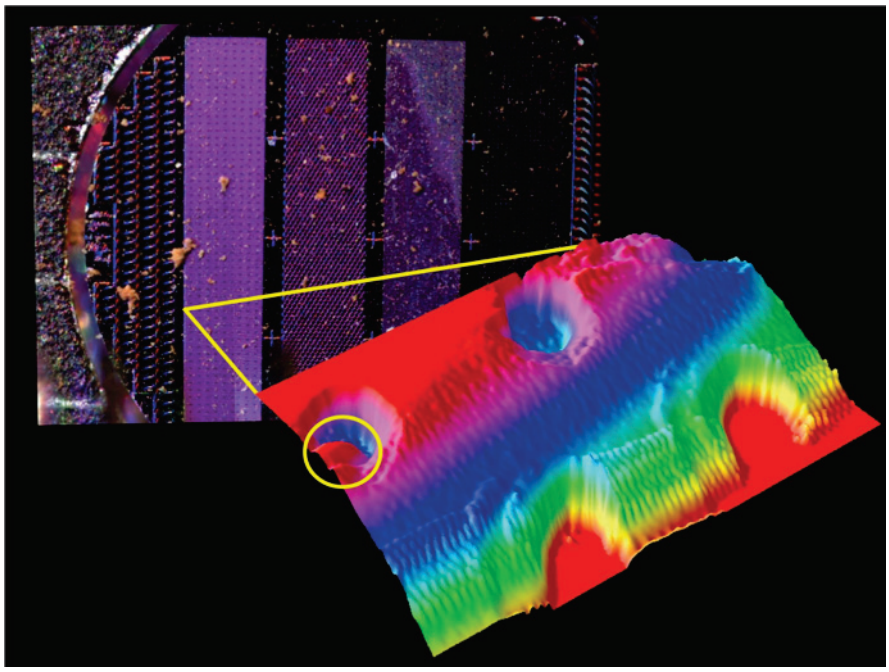

Figure 1. "Images from Phoenix's MECA Instruments." Image NASA/JPL-Caltech/ University of Arizona/University of Neuchatel

In a move straight out of the *Fantastic Voyage* playbook, NASA has pasted images from two different scales together in the same frame. The resulting composite serves to collapse scale, suggesting that the two parts of this overlapping image are simply two snapshots on a scalar continuum. The superimposed yellow lines represent this speculative scalar gradient. Of course, one image is produced by photons striking a sensor, while the other is produced by algorithmically transforming a dataset of voltage differences into a vector graphic according to NASA's own programmed parameters. Only their overlapping Photoshopped presentation, the superimposed lines, and the rhetoric of magnification stabilize this image as representing a spatial continuum. Images such as these suggest that matter looks and acts the same at all scales, effectively eliding differences between the nanoscale and the microscale.[5]

Both constitutive images have as their subject the Mars Lander itself. In the optical layer, we can see bits of crushed Martian rock crumbled onto the Lander's sample detection surface. In the AFM layer, the (optical) distinction between Martian rock and Lander metal is eviscerated. The bright, false color added to the image and the homogeneous texture of the topo-style map render it, for a human viewer, as once again a landscape. Thus while the microscopic layer reads as magnification, the AFM layer reads as opened landscape, terrain ready to be explored, milieu rather than object.

[5] Significant differences between the macroscale or microscale and the nanoscale include, *inter alia*, the absence of gravity as a significant force, the introduction of bonding and other forces as significant, a decrease in inertia and corresponding increase in the speed of roughly analogous actions and movements, a radically different relationship between surface area and volume, completely different optical properties, and the near-lack of completely stable forms. For a useful overview, see for example Goddard 2007, section 10.3.

NASA's own description of this image asserts that it is "the most highly magnified image ever seen from another world" (NASA 2008). The visual and textual assemblage of the entire composite image highlights a process of exploring an alien world, and thus the technological prowess embodied in the robot itself. The multi-decade, technoscientific, American project of the search for life on Mars and U.S. "Manifest Destiny" are here extended to two different scales simultaneously, enlarging the scope of both the exploratory mission and its discursive positioning of the U.S. as technological pioneer and neo-colonial superpower at the same time. Colonizing other worlds turns out to be a process of looking at oneself, enacting a transcalar gaze that collapses the difference between two scales and utilizes this collapse to drive the (re)production of material and ideational forms: in this case the circulation of images that help to establish the priority of the human scale, the framing of technology as human prosthesis (McLuhan 1966; Rothenberg 1995), and the ideology of U.S. Manifest Destiny.

3. Baconian Utopia and Neoliberal Economics

As atmospheric CO_2 concentrations continue to skyrocket and global climate change accelerates, geoengineering proposals have picked up advocates among certain climate scientists, private funding sources such as the Gates Foundation, and some members of the general public (Kintisch 2010; Fleming 2012; Parkhill and Pidgeon 2011). Several agencies of the U.S. government, including the Central Intelligence Agency, have recently announced a major geoengineering feasibility and risk study (Aldhous 2013). Like nanotech discourse, geoengineering harnesses a scalar differential, discursively collapses it using various medial technologies and tropes, and thereby drives the production of narratives, images, legislative proposals, and material objects. While nanotech discourse harnesses the difference in scale between the human and the molecule, geoengineering harnesses the scalar difference between the human and the planet. In both cases, the *human* or *macro* scale is privileged in the same way. This invisible norming process is analogous to gender asymmetry in language. Most Indo-European languages privilege the masculine form of nouns as unmarked and require the feminine to be specially marked, with the social implication that masculinity becomes the norm, or absolute, while the female or feminine becomes "Other" (Beauvoir 2011, 5). Similarly, in much nanotech and geoengineering discourse, the human scale becomes unmarked (normal, assumed, absolute) and the nano- or the geo-scale becomes Other.

As a discourse, geoengineering combines the technoscientific ideal of mastery over "nature" with what Lewis Mumford calls the "giantism" of the "paleolithic age" of eighteenth- and nineteenth-century engineering (Mumford 1963) and the nonlinear feedback loops of cybernetic theory (Weiner 1961). As numerous scholars have noted, Francis Bacon set the stage for contemporary technoscience as early as 1627, when the English version of his utopian *New Atlantis* was published posthumously. Jan Schmidt has recently argued that Bacon's "real-constructivist" epistemology set the stage and adequately accounts for the ontological and epistemological status of the objects created by nanoscience. He argues that, for Bacon, our reality is constructed by the objects humans create and deploy in the testing (Bacon: "vexing") of nature: "Facts are rooted in actions" (Schmidt 2011). In the same way that nanoscientists vex individual atoms with their devices—and thereby make new molecular configurations just as they make new AFMs—geoengineers propose to remake the climate by inventing and deploying new technical systems. Geoengineering, even in its speculative mode, thus represents

Baconian knowledge production through technics. In Bacon's *New Atlantis*, he describes the fictional island of "Bensalem," run by a rationalist population that has established a state-funded scientific research and development institution called "Salomon's House." Remarkably, one of the activities carried out in Salomon's House is weather modification:

> We have also great and spacious houses where we imitate and demonstrate meteors; as snow, hail, rain, some artificial rains of bodies and not of water, thunders, lightnings; also generations of bodies in air; as frogs, flies, and divers others. (Bacon 2008, 481)

Here Bacon describes a particular laboratory that specializes in weather modification and spontaneous, or abiotic, generation. In his fictional research community, these two activities are assigned to the same house, or laboratory. Their experimental commonality seems to lie in their atmospheric deployment and their *ex nihilo* form of production. It is not difficult to see, here, the foundations of geoengineering and nanotechnology as imaginaries: on one hand the conjuring of large-scale weather patterns at will, on the other the rearrangement of fundamental matter to produce new forms, seemingly out of nothing.[6] A representative of Bensalem explains that "The end of our foundation is the knowledge of causes, and secret motions of things; and the enlarging of the bounds of human empire, to the effecting of all things possible" (Bacon 2008, 480). As we have seen, "enlarging the bounds of human empire," whether into the body or onto distant planets, is often figured in nanotechnological discourse as a process of scalar enlargement, of encountering phenomena at other scales and rendering them as vast landscapes to be explored in a human-scale milieu, either by humans themselves or by their technological prostheses (cameras and robots). This process, which I have called "scalar collapse," assumes an anthropocentric starting point for all knowledge production and technoscientific development. As Bacon indicates, the process of uncovering the causes and "secret motions" of material objects is part and parcel of the project of human domination and colonization of these objects, a project that proceeds not reactively, but proactively, through the controlled production of the phenomena (artificial weather, engineered organisms) themselves. Because the House of Salomon proceeds on the basis of experimentation and induction rather than deduction, large-scale, complex systems such as the global climate are easily reduced to sets of procedures that can be implemented at any scale. As Hugh Lacey emphasizes, the control of nature under this schema implies and in fact requires a search for the "material possibilities of things" (Lacey, 1999, 13). Complex systems do not need to be understood in their entirety; it is enough that the technoscientist be able to perturb them to unleash their potential in predictable ways—that is, for human ends. These human ends are typically local and economically motivated, as in Russ George's 2012 act of "rogue geoengineering" which involved the dumping of 120 tons of iron sulfate into the ocean off the coast of Haida Gwaii (Lukacs 2012; Biello 2012).

This figuring of scientific knowledge as produced through technics and put into service for pre-determined human ends underwrites the geoengineering imaginary and authorizes its access to the planetary scale. Roger Fleming notes that current geoengineering proposals are "heirs to a long and checkered history of weather and climate

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[6] Sophie Weeks reminds us, however, that for Bacon nothing can truly be created *ex nihilo*. Successfully producing the forms that one desires requires an intricate understanding of nature's potentials. Humans recombine elements from nature, but nature does the actual work of producing these forms, acting according to its "appetitive nature" (Weeks 2007). Compare to Eric Drexler's vision of nanofabrication at will (1986, 63).

control" and embedded within a larger set of cultural narratives of "gods and heroes who have attempted to control that which may be largely uncontrollable, including phenomena both above and below the horizon" (Fleming 2010, 13, 15). The weather, symbolizing both the uncontrollable and the large-scale, has long been the conceptual horizon for technics. To control the weather is to stabilize the agency of the human, to shore up its scalar efficacy. Stewart Brand makes this clear in his book-length argument for geo-scale technics, *Whole Earth Discipline*: "Gaia is no savior, since 'she' likes ice ages and doesn't mind hot ages either. We're left with intention, with conscious design, with engineering. We finesse climate, or climate finesses us" (Brand 2009, 19). The scalar collapse produced by such formulations is clear: the earth, as singular organism (Gaia) interacts with and modifies the human without any regard to its wellbeing. The earth becomes, here, something like a careless neighbor rather than an encompassing milieu. Brand concludes that it is "our obligation to learn planet craft, to be as life-enhancing as any earthworm, in the big yard" (Brand 2009, 23). The lowly earthworm manages its environment and so should we. Here the planet-scale environment is conceptually shrunk to an oversized yard, a demarcated space to be managed and harnessed as a human-scale property. Just as the nano-milieu is transformed into a human landscape by speculative nano-discourse, the planet is shrunk by an engineering discourse that calibrates its scale relative to a single species and gives it meaning by instilling purpose in the form of human "intention" and "conscious design."

The anthropocentric fantasy of having the earth in the palm of our hand is of course a political one. Considered as an abstract diagram, geoengineering discourse often produces a scalar reduction (analogous to the conceptual scaling operation of enlargement in nanotech) of the earth to the human scale along social, economic, and political gradients. Moreover, it is *productive*, harnessing a scalar differential (between the human and the planet) to produce a convergence between technoscientific control, geopolitical control, and neoliberal economics. Free-market fundamentalist Bjørn Lomborg, the "skeptical environmentalist," has enthusiastically embraced geoengineering as a market-based "solution" to climate change, allowing carbon-intensive energy production to continue unabated until alternative energy becomes cheaper than fossil fuels. Lomborg advocates abandoning the Kyoto Protocol and almost all carbon mitigation efforts, and spending money on geoengineering and alternative fuel research instead (Lomborg 2007; *Cool It* 2011). Lomborg's documentary film tie-in to his 2007 book of the same name, *Cool It*, argues that a purely "rational" cost-benefit analysis suggests that we can solve our *human* needs for far less money than regulating carbon emissions, while continuing to support the economic status quo. This "solution" is enabled by a conceptual scalar reduction.

The film opens with a shot of a glowing planet Earth suspended in the center of the frame, which is then cut with a misshapen children's drawing of the same, crudely drawn and colored in as if with crayons. "Well this is like the earth," intones an off-screen child, "and what it's going to be like." Successive versions of the crayon earth flash across the screen, depicting deserts and rising sea levels. The sequence culminates with a partially seen Earth engulfed in flames in the lower portion of the frame, while a frowning child, drawn in the same style, looks down at it from the upper right portion of the frame. The crayon-drawn conflagration quickly engulfs the child and globe alike. This sequence, a masterful parody of environmentalist concerns about global warming, nearly perfectly embodies the scalar collapse of geoengineering media. The planet first appears to be isolated in inky black space, both a pale blue dot and an all-encompassing milieu. Through a set of inscriptive transformations, however, it becomes the object of

human design. The human subject then regards these changes to the planet's surface disapprovingly, the Earth itself reduced to approximately the same scale as the human subject whose gaze dominates the frame. This sequence also neatly captures the logic of Lomborg's neoliberal project: apocalyptic fears of the planet's demise are not dissolved so much as harnessed to promote an economic platform. The apocalyptic fire prophesied by the environmentalists will not occur precisely because global capital has made the human scale-commensurate with the planet. As Lomborg summarized in his first book, economic analysis "can give us new faith in the fact that we are involved in creating a better world by taking part in society's production of assets, tangible as well as intangible . . . We have become richer and richer primarily because of our fundamental organization in a market economy and not because we have worried" (Lomborg 2001, 351). Instead of modifying human activity to save the planet, we can erase the crayon fire and accept the rest of the image at face value. The earth can be reshaped however we wish: its possibility space is defined by the human subject, its material potentials colonized and managed as "society's assets." Nonetheless, the "better world" that global capital is creating faces externalities (non-economic interventions) such as sea level rise, temperature rise, and desertification. In order to keep these in check, Lomborg became perhaps the world's most famous advocate of geoengineering in 2009 (Broder 2009; Lomborg 2010).[7] In his documentary he claims that we "need to have a stopgap measure if things could turn out to be much worse than we expected, and/or if we need some extra time in order to be able to phase in the green energy." He argues that by investing in geoengineering, "We can tackle the global warming impacts by focusing on sea level rise—thirty billion dollars—on inland flooding—about six billion dollars—and urban heat islands . . . And we can solve all the major remaining problems in the world" (*Cool It* 2011).

Rather than approaching the planetary milieu as conceptually larger and more complex than the human, geoengineering proposals such as Lomborg's discursively reduce its dimensional complexity and subject it to a speculative horizon of complete human control. The global market economy acts as scalar mediator, leveraging the productivity of unregulated global capital as a planetary cure-all. Of course, these proposals must content themselves with treating only the *symptoms* of global climate change that affect our species most directly, as I will discuss below. Lomborg's film ends with a series of macro close-ups of children's blue corneas intercut with the crayon Earth being recolored yellow, green, and blue, and finally, in the poles, white: a speculative completion of Bacon's utopian vision.

4. Levitating Particles

Geoengineering proposals generally fall into one of two categories: those that propose methods by which CO_2 could be extracted from the atmosphere and sequestered in some other form ("carbon dioxide removal" or CDR), and methods that reduce the amount of light entering the Earth's atmosphere by blocking a fraction of the sun's rays

[7] Lomborg's platform, elaborated and disseminated by his "Copenhagen Consensus" think tank, revolves primarily around discrediting environmentalist assessments of impending crises. In line with nearly all neoliberal economists, he positive program consists of promoting free market capitalism as a general cure for the world's problems. His recommendations tend to favor deregulation, high levels of public funding for green energy research, and high levels of public funding for geoengineering research.

("solar radiation management" or SRM). By far the most controversial and least expensive of these proposals involves the systematic, widespread release of sulfate aerosols into the upper atmosphere (Royal Society 2009). This form of geoengineering does nothing to reduce CO_2 concentrations in the atmosphere; instead it distributes reflective particles there to block some of the sunlight that would ordinarily reach the earth's surface, with the effect of decreasing the overall albedo of the planet and effectively, if temporarily, cooling it. This method fails to address the underlying cause of global climate change, treating only one of its symptoms: average global temperature rise. It thus introduces a series of risks: of unknown side-effects on a global scale, of a "moral hazard" in that it would likely deter efforts to reduce carbon emissions, and of the unchecked increase of other effects of global climate change such as ocean acidification. The sudden halt of spraying "could lead to a relatively rapid warming which would be more difficult to adapt to than the climate change that would have occurred in the absence of geoengineering" (Royal Society 2009, 35).

Geoengineer David Keith has long been a proponent of studying the sulfate aerosols method (Keith and Dowlatabadi 1992), but has recently developed an enhanced proposal that incorporates advanced nanotechnology. Instead of spraying simple aluminum or other metallic particles (including nanoparticles) that slowly disperse and fall to the ground, which would require daily spraying around the globe with tens of thousands of planes, Keith proposes that we engineer a new class of particles that are essentially discs with a wide surface area, out of a layered composite of aluminum oxide, aluminum, and barium titanate (figure 2). Engineered so that one side of the discs heat much faster than the other, reflective side, they effectively harness the "gravito-photophoretic force" in order to "levitate" in the mesosphere for periods as long as years (Keith 2010, 2).

Keith's synthesis of nanotechnology and geoengineering is an exemplary case of speculative engineering that functions by harnessing scalar differentials. Here the scale of the nanoparticle is discursively articulated to the scale of the planet. Keith's proposal suggests that the global climate can be precisely programmed by scientists through the novel engineering of particles at the nanoscale. It thus invokes a scalar continuum from the particle to the planet, colliding these scales together and collapsing the difference between them: the precision of nanotechnology (one particle at a time) and the characteristics of the nanoscale are transposed onto the global climate system.[8] Where previous proposals (sulfate aerosols) appeared as almost comically imprecise interventions into planetary climate dynamics, Keith's levitating disc proposal harnesses the social prestige and potent cultural imaginary of nanotechnological control over fundamental matter to render geoengineering—as an imaginary in its own right—more plausible. Can humans really control global climate dynamics that are far more complex than they can ever directly experience or potentially even understand? How is this gulf of scale to be breached? These are the questions that geoengineers must answer before geoengineering discourse will achieve widespread public acceptance. Keith moves in this direction through a unique scalar deferral: in his geo-vision, humans take control of global dynamics by mastering the nanoscale. If molecules can be directly manipulated to form levitating discs, then nanotechnology itself can be articulated to any other scale through the process of replication: once we have the "right" nanoparticle, nanotech techniques can produce as many of them as needed for any particular task (Drexler

[8] In this case, the dramatically different relationship between surface area and volume at the nanoscale, along with the decreased importance of gravity, together make levitation possible.

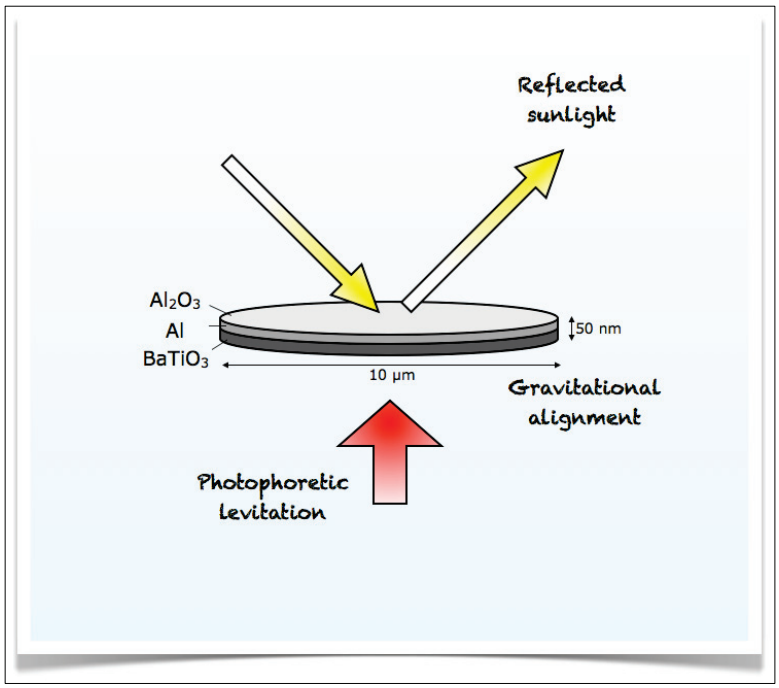

Figure 2. Proposed self-aligning, levitating, sunlight-reflecting nano-disc. Courtesy of Andrew Maynard.[9]

1986). The burden of precise control of chaotic systems is discursively placed on the nanoscale rather than the planetary scale, and geoengineering comes to seem more plausible (if less imminently achievable). But even while nanotechnology is employed to do the heavy lifting for the geoengineering cultural imagination, the human remains the unmarked scale. "From nano to geo" describes a discursive-scalar operation that bisects the human. In Keith's proposal, it is the unmarked "middle" scale that mediates the relationship between nanoparticles and global climate systems and thus "enlarges" its own technoscientific "empire."

Conclusion: Scalar Difference as Ecology

Physicist and television science promoter Jonathan Hare has produced a nearly perfect emblem of scalar collapse, "Hare's ratio." Sir Harold W. Kroto, one of the members of the team that discovered C_{60} (buckminsterfullerene) in 1985, dubs Hare's ratio "the last fundamental physical constant" (Kroto 2001, 229). Hare's observation is this: the ratio between a single buckminsterfullerene molecule and a soccer ball is approximately the same as that between a football (soccer ball) and the Earth (Kroto 2001, 227). Hare thus formalizes the scalar continuum evoked by the various scalar media I have exam-

[9] Maynard is a scientist and policy expert who created this illustration of Keith's proposal for his own blog, *2020 Science* (Maynard 2010). I have used it here because I consider it to be more clear and expressive than Keith's own illustration.

ined in this chapter. By substituting an invariant mathematical ratio for scalar difference, Hare suggests the existence of a necessary connection between these three objects. The point is perspectival: instead of asking, for example, what cultural, social, and material forces have collectively generated our institutionalized preoccupation with the nanoscale (out of all other possible scales), or how the nanoscale behaves differently from the human scale or the planetary scale, the difference between these scales is elided, evoking what we might describe as a "scalar destiny." Was the soccer ball destined to exist in the same way that sixty atoms of carbon form a geodesic molecule under certain conditions? While Hare's ratio doesn't seem to have any scientific implications, it has plenty of ideological ones. Rhetorically, his ratio activates a quasi-religious notion of scalar relationships, a sense that everything is in its optimal place. The human scale appears at the center of this perfect internal unity, as if created by God at and as the center of the universe, hearkening back to the scalar affordances of Ptolemaic cosmography.

The question of scalar difference could also be called the question of ecology. As anthropogenic climate change reveals catastrophic transcalar effects—where seemingly harmless events at one scale have disproportionate effects at other scales—thinking the scalar other is rapidly becoming an imperative of collective intellectual endeavor. Both nanotechnology and geoengineering rhetorically and substantively engage radically other scales and position their respective traditions and institutions as potential technological "fixes" for our ecological woes. It is vitally important, then, to investigate the way that these discourses frame and construct our transcalar relationships. Why is it, I think we must ask, that our engagements with objects that occupy radically disparate scales so frequently end up merely articulated to a re-centered human scale? Why and how are these transcalar encounters reduced to scalar collapse even as cultural appreciation for scalar difference has become so urgent?

The discursive forms traced in this chapter function primarily in a speculative mode, formulating narratives of possible futures even when they make claims about the present or past. I have highlighted a number of concrete examples of scalar collapse and attempted to trace in each case the process by which representational technologies mediate between the viewer and other scales, producing an experience I call "speculatorship." In these cultural narratives and mediated experiences, the human individual—rendered speculatively contiguous and commensurate with the atom and the planet—occupies a privileged scalar position. As Peter Duval declares in *Fantastic Voyage*, "The medieval philosophers were right. Man *is* the center of the universe. We stand in the middle of infinity between outer and inner space, and there's no limit to either" (*Fantastic Voyage* 1966). I would like to suggest that abdicating this position, learning to think other scales in all of their complexity and difference, will increase the potential for scientists and laypeople alike to engage objects at nano- and geo-scales in more generative, sustainable, and creative ways.

References

Aldhous, P. (2013) 'CIA Spooks Investigate Geoengineering to Fix Climate,' *New Scientist*, http://www.newscientist.com/article/dn23898-cia-spooks-investigate-geoengineering-to-fix-climate.html.

Bacon, F. (2008) *New Atlantis.* In *Francis Bacon: The Major Works*, B. Vickers (ed.), Oxford: Oxford University Press.

Beauvoir, S. de. (2011) *The Second Sex*, C. Borde and S. Malovany-Chevallier (trans.), New York: Vintage.

Bensaude-Vincent, B., Loeve, S., Nordmann, A., and Schwarz, A. (2011) 'Matters of Interest: The Objects of Research in Science and Technoscience,' *Journal for General Philosophy of Science* 42(2): 365–383.
Biello, D. (2012) 'Pacific Ocean Hacker Speaks Out,' *Scientific American*, http://www.scientificamerican.com/article.cfm?id=questions-and-answers-with-rogue-geoengineer-carbon-entrepreneur-russ-george.
Brand, S. (2009) *Whole Earth Discipline: An Ecopragmatist Manifesto*, New York: Viking.
Broder, J. M. (2009) 'A Skeptic Finds Faith in Geoengineering,' *Green Blog*, http://green.blogs.nytimes.com/2009/09/03/a-skeptic-finds-faith/
Cool It (2011) O. Timoner (dir.), 1019 Entertainment and Interloper Films.
De Landa, M. (2000) 'Deleuze, Diagrams, and the Genesis of Form,' *Amerikastudien/American Studies* 45(1): 33–41.
Deleuze, G., and Guattari, F. (1987) *A Thousand Plateaus: Capitalism and Schizophrenia*, Minneapolis: University of Minnesota Press.
Drexler, K. E. (1986) *Engines of Creation*, Garden City, NY: Anchor Press/Doubleday.
Dyan, D. (1974) 'The Tutor-Code of Classical Cinema,' *Film Quarterly* 28(1): 22–31.
Fantastic Voyage (1966) R. Fleischer (dir.), 20th Century–Fox.
Fleming, J. R. (2010) *Fixing the Sky: The Checkered History of Weather and Climate Control*, New York: Columbia University Press.
Gimzewski, J., and Vesna, V. (2003) 'The Nanomeme Syndrome: Blurring of Fact and Fiction in the Construction of a New Science,' *Technoetic Arts: A Journal of Speculative Research* 1(1): 7-24.
Goddard, W. A., III, Brenner, D., Lyshevski, S. E., and Iafrate, G. J. (eds.) (2007) *Handbook of Nanoscience, Engineering, and Technology,* 2nd ed., Boca Raton: CRC Press.
Keith, D. W., and Dowlatabadi, H. (1992) 'A Serious Look at Geoengineering,' *Eos* 73(27): 289, 292–293.
Keith, D. W. (2010) 'Photophoretic Levitation of Engineered Aerosols for Geoengineering,' *Proceedings of the National Academy of Sciences* 107(38): 16428–16431.
Kintisch, E. (2010) *Hack the Planet: Science's Best Hope—or Worst Nightmare—for Averting Climate Catastrophe*, Hoboken, NJ: Wiley.
Kroto, S. H. W. (2001) 'Macro-, Micro-, and Nano-scale Engineering.' In T. T. K. Zung (ed.), *Buckminster Fuller: Anthology for the New Millennium*, New York: St. Martin's Press.
Lacey, H. (1999) 'Scientific Understanding and the Control of Nature,' *Science and Education* 8(1): 13–35.
Loeve, S. (2011) 'Sensible Atoms: A Techno-Aesthetic Approach to Representation,' *NanoEthics* 5: 203-222.
Lomborg, B. (2001) *The Skeptical Environmentalist: Measuring the Real State of the World*, Cambridge: Cambridge University Press.
Lomborg, B. (2007) *Cool It: The Skeptical Environmentalist's Guide to Global Warming*, New York: Knopf.
Lomborg, B. (2010) 'Geoengineering: A Quick, Clean Fix?' *Time*, http://www.time.com/time/magazine/article/0,9171,2030804,00.html
Lukacs, M. (2012) 'World's Biggest Geoengineering Experiment "Violates" UN Rules,' *The Guardian*, http://www.guardian.co.uk/environment/2012/oct/15/pacific-iron-fertilisation-geoengineering.
Maynard, A. (2010) 'Could Precisely Engineered Nanoparticles Provide a Novel Geoengineering Tool?' *2020 Science*, http://2020science.org/2010/09/13/could-precisely-engineered-nanoparticles-provide-a-novel-geoengineering -tool/.
McLuhan, M. (1966) *Understanding Media: The Extensions of Man*, 5th printing, New York: McGraw-Hill.
Milburn, C. (2008) *Nanovision : Engineering the Future*, Durham: Duke University Press.
Mumford, L. (1963) *Technics and Civilization*, New York: Harcourt Brace and World.
NASA (2008) 'Images from Phoenix's MECA Instruments,' *NASA*, http://www.nasa.gov/mission_pages/phoenix/images/press/AFM_prt.htm.
Oliveri, M. (2010) 'Innerspace Nano Landscapes,' *Michael Oliveri*, http://michaeloliveri.com/wp/?p=807.
Oxford English Dictionary, 'magnification, *n.*' *OED Online*, Oxford University Press, http://www.oed.com/view/Entry/112323.
Parkhill, K., and Pidgeon, N. F. (2011) 'Public Engagement on Geoengineering Research: Preliminary Report on the SPICE Deliberative Workshops,' Technical Report (Understanding Risk Group Working Paper, 11-01), Cardiff University School of Psychology. Available at http://psych.cf.ac.uk/understandingrisk/docs/spice.pdf.
Patowary, K. (2009) 'Landscapes from the Nano World by Michael Oliveri,' *Amusing Planet*, http://www.amusingplanet.com/2009/01/landscapes-from-nano-world-by-michael.html.
Rip, A., and Ruivenkamp, M. (2012) 'Affordances of Nanoscale Images.' In H. van Lente, C. Coenen, T. Fleischer, K. Konrad, L. Krabbenborg, C. Milburn, F. Thoreau and T. B. Zülsdorf (eds.) *Little by Little: Expansions of Nanoscience and Emerging Technologies*, Heidelberg: AKA Verlag/IOS Press.
Rothenberg, D. (1995) *Hand's End: Technology and the Limits of Nature*, Berkeley: University of California Press.

Royal Society (2009) 'Geoengineering the Climate: Science, Governance, and Uncertainty,' *Royal Society*, http://royalsociety.org/policy/publications/2009/geoengineering-climate/.
Ruivenkamp, M., and Rip, A. (2010) 'Visualizing the Invisible Nanoscale: Study of Visualization Practices in Nanotechnology Community of Practice,' *Science Studies* 23(1): 3–36.
Schmidt, J. C. (2011) 'The Renaissance of Francis Bacon: On Bacon's Account of Recent Nano-Technoscience,' *NanoEthics 5*(1): 29–41.
Weeks, S. (2007) 'Francis Bacon and the Art–Nature Distinction,' *AMBIX* 54(2): 101–129.
Wiener, N. (1961) *Cybernetics: or Control and Communication in the Animal and the Machine*, Cambridge, Mass.: MIT Press.