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The Rhetoric of Nanotechnology

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Abstract. The following examines the special needs for communicating risk, especially risks associated with newly emerging technologies such as nanotechnology. The public is not receiving a lucid message from the many narratives. Scientists have begun to address the public directly with mixed results especially since the public is unprepared for the messages and the media fails to offer much assistance. The rhetorical strategies undertaken by proponents are examined with a case study. K. Eric Drexler advocated a self-assembling nanobot molecular manufacturing brand of nanotechnology. His rhetoric has buried the concept under layers of metaphorical obfuscation and has been detrimental to a coherent message.

Introduction

Technology is neither inherently liberating not enslaving, neither decentralizing nor centralizing. Which approach to technology is embraced and the process of its implementation determine the relationship between purveyors and consumers. Whether democracy in the current millennium more reflects its roots found in the Athens city-states or the constitutional Republicanism of post World War II America and Western Europe may depend on technology related decisions. Well into the Information Age, it may be too late to smash the machines – eradication is no longer an option. What must be done probably involves citizen-consumers becoming integrated into the decision-making process. When technological discourse happens, citizen-consumers need to participate in these discussions and when decisions are to be made; citizen-consumers must be empowered to affect decisions.

Contemporary technological discourse is shameful. Leaders who wish to recommend options and sometimes policy call upon experts. Heavily biased by personal and professional interests, experts craft their messages so they are resistant to most counterclaims. For example, by using excessively technical vocabulary, their arguments become arguments from authority. When asked "why is that true?" their response generally is "Don't you understand? I do. I have an advanced degree!" As a result, citizen-consumers are frozen out of depthful discussions on issues involving science and technology, especially those related to decision-making. When an occasional miscreant speaks up, he is derided, labeled, or patronizingly dismissed.

Unsurprisingly, when citizen-consumers are involved in science and technology decision-making, it is usually during the post-decision implementation phase. For example, a decision might be reached to build a toxic waste incinerator with citizen-consumers only called in for input on deciding where it might be located. Even then, in many cases, the location has already been decided and citizen-consumers vent their reservations in public meetings and are lectured to by public relations specialists whose job it is to sate, defuse, and demobilize opposition. In some cases, the means they employ may involve misrepresentations and downright lies.

The challenge for today's developed and developing world must be to find ways for citizen-consumers to become entrenched in the decision-making process early enough to counteract, at least restrain, the interests of transnational corporate profit making. There have been too many examples of selfishness, greed, and apathy by corporate structures toward the social, environmental and economic interests of the citizen-consumers on whom they often prey. Bhopal, India, Times Beach, Missouri, and Niagara Falls (Love Canal), New York, are only three illustrations, but they suggest that corporatism cannot be depended on to check itself.

In response, we have mostly opted for increasing government oversight and regulation. Though not an apparently undesirable response, it tends to further centralize power vertically.

However, we are at a crossroad. We may want to reduce pressures for greater authority as a weapon against irresponsible corporate action. By becoming involved in the earliest decisions, citizen-consumers can do their part to preclude the growth of governmental regulatory hierarchies. Authority is more likely to become more powerful as responses become more remedial in nature.

1. Foundations

While the rhetoric of science has been approached in the works of Alan Gross (1996) and Lawrence Prelli (1989), much less emphasis has been given to the rhetorical dynamics associated with technology. (In all honesty, it must be observed that the primary source of much that can be found in the rhetoric of science has been borrowed unabashedly from the philosophy of science).

It seems that scholars in communication have decided that the only voices associated with technology are those of its proponents and opponents. Proponents include chief operating officers of private companies seeking venture capital, government officials supporting policies that would serve technological firms in their home districts, public relations officers often acting as apologists, and technophiliacs, including grant directors, who preach technology as the cure-all for society's woes. Opponents include critics suspicious of the overclaims associated with technology, pragmatists who are responsible for coordinating government budgets against technological promises, and technophobes (Neo-Luddites) some Green some not who blame technology for most of the world's ills.

2. New Challenges

Rhetoric is no longer defined as the art of discovering the available means of persuasion. In more recent times, it has been defined as the constructive art of making knowledge. While traditional rhetorical studies have examined speakers and audiences, technology has a voice as important as the technologists' in terms of its impact on our lives.

Technology as artifact is highly suasive. If technology is the art of producing useful objects and we can accept the basic premise that rhetoric goes beyond the podium and includes such things as design discourse and scientific discovery, then the rhetoric of technology has to do with ways we use discourse to construct objects both metaphorically, if not metaphysically, and meaningfully.

The rhetoric from technology includes arguments that characterize our way of thinking as consumers of technology; especially in the way we devalue our abilities to control technology by delegating our agency to the machines and placing ourselves in subordinate or passive roles.

3. New Technologies

When it comes to nanotechnology, it becomes much more complicated. Nanotechnology speaks with a unique voice. Beyond scientists, venture capitalists, and science journalists, nanotechnology as an artifact of science has its own voice; it speaks as a plethora of actual nano-discoveries and virtual nano-promises, especially the assembler. The audience is composed of investors, the media, competitors, and policy-makers as well. While the arguments are built of speculative data and tentative warrants, they seem to be attracting larger audiences, the psychology of which is too dense to examine here. Simply put, a strangely weak argument is highly effective and that may be due to some extraordinary characteristics of the nanotechnology debate, especially within the United States.

Some of the characteristics of this debate that are confounding communication scholarship include but are not limited to the following.

First, the field is multi- or interdisciplinary, hence the voices come from a jumble of fields and disciplines. While the chemist may understand the biologist and the engineer, they do not make the same types of arguments. Further complicating the discord is the intersectional voice coming from chemical engineers, biotechnologists, and others who are in interdisciplinary fields already but find themselves hip deep in another multidisciplinary one.

Second, nanotechnology is here in size only. Simply put, nanoscience functions in the realm associated with the prefix nano-. However, the technologies that are likely to fulfill some of the claims made by proponents have not materialized. The assembler remains a pipedream and mass production of nanobots a fantasy construct. Nonetheless, the claims and counterclaims of benefits and risks associated with applied nanotechnology continue unabated. Critics of technology have found another artifact to flog.

Third, there seems to be some legitimate concern within the halls of Congress at least that mature nanotechnology might be problematic. Neal Lane and Mihail Roco notwithstanding, government regulators remain unconvinced that nano is the word. See, for example, recent demands that a bona fide SBE component (social, behavior and economic sciences) be included in NSF grant applications, including the NNIN (National Nanotechnology Infrastructure Network). As such, the debate over benefits and risks is being fed from above as well.

Fourth and associated with SBE concerns, many individuals and institutions seem concerned with the absence of a legitimate public sphere that can intelligently debate nanotechnology. As Americans become less and less versed in issues associated with science and technology beyond the least expensive mobile phone service and Internet service provider, science and technology plod onward. Some scientists and technologists are equally fretful that the reaction to genetically modified organisms, especially foods, may be repeated with the advent of nanotechnological products.

4. Communication Studies

Most communication studies of technology have been associated with risks and crises. They are subject specific, such as “The Challenger Disaster” or “Three Mile Island” or they are general examinations of the impact of technology on traditional political rhetoric, especially democracy and the public sphere. The two leading fields of communication are outlined below.

5. Crisis Communication

Crisis communication comes in pre-emptive and reactive flavors. In general, it refers to emergencies like fires, bomb threats, natural disasters, or major crimes. Controversial issues may include police investigations, protests or other situations that demand a public response. The directives hands-on consultants advocate are pretty much the same. Crisis means victims and explosive visibility. Bosses need trusted advisors and counselors who can offer focused, pragmatic, and useful advice that help them deal with difficult situations strategically and immediately, while limiting collateral damage. Using powerful case examples, participants will explore a series of crisis communication management problems and strategies while immersed in the same management struggles, confusion, decision-making, dilemmas, and moral challenges managers face. Case studies involve managing victims, reducing litigation, recovering reputation, healing corporate wounds, dealing with organized opposition, selectively engaging the media, Web attack survival, and influencing employee, community, and public attitudes.

The following was drawn from North Carolina State University's crisis policy[1]

1. To factually assess the situation and determine whether a communications response is warranted.
2. To assemble a Crisis Communication Team that will make recommendations on appropriate responses.
3. To implement immediate action to:
    a. Identify constituencies that should be informed about the situation.
    b. Communicate facts about the crisis.
    c. Minimize rumors.
    d. Restore order and/or confidence.

While hardly insightful, recommendations like these stoke the coffers of small communication firms run by self-acclaimed experts and are the product of government grants newly supported by the Department of Homeland Security.

6. Risk Communication

Both Ehrlich and Ornstein argue humankind has a difficult time evaluating incremental risks. They claim we are developmentally much like our forebears who were creatures who reacted to threats and crises. When a bear appeared at the mouth of our cave, we hid or tried to fight it off (Ehrlich & Ornstein 1989). When we are confronted by events we do not understand, we lash out at it a lot like Cro-Magnon man, poking at a mass with his stone axe and clubbing it once it moved.

7. Defining Risk: A Primer on the Language of Risk

Risk pervades the world we inhabit. Whether of small or large magnitude, risk is a concept that everyone encounters (consciously or unconsciously) regularly and often.

In addition, public knowledge about science is limited, especially a subject as exotic as nanotechnology. Frank Press, President of the National Academy of Sciences, writes: "Opinion surveys and tests of U.S. students' knowledge show that public understanding of science and technology is weak. Even Americans with advanced training in non-scientific fields often know little about the revolution in biology or the amazing new materials being produced in laboratories" (Press 1991, p. ix). Indeed, if persons actually attempt to read or learn about science and the risks associated with it, they often have "limited access to expert opinion leaders to help interpret scientific and technical information" (Hornig 1990, p. 768).

Enter the public sphere. Traditionally, journalists replaced scientists as the "experts" defining risk levels. This has begun to change as third culture intellectuals, including Drexler, came along. Nevertheless, both use language. Whether intentionally or not, journalists and Drexler, himself, sometime obscure meaning by using words and terms, which underplay a problem and overplay a benefit. This framing process of encoding messages is hardly accommodating informed consent.

However, removing scientists from the calculus is not an answer. Moreover, there are times when the scientific community itself can be locked out in the decision-making processes. For example, "metaphors in science journalism cluster and reinforce one another, creating consistent, coherent, and therefore more powerful images which often have strategic policy implications" (Nelkin 1987, p. 81). The resulting communication tends to move towards polarization, generally becoming either overly complex or overly simplistic. Since simplified language is more approachable, it crowds out complex, though much more accurate and meaningful, scientific language.

Even the best public relations professionals have been unable to communicate objective assessments of risks, especially after a crisis. For example, in 1989, at the peak of its nuclear power usage, "nuclear generation produced only 18 percent of American electricity" (Jasper 1990, p. 90). Given the accidents at Three Mile Island and Chernobyl, and the realization that nuclear power accidents were bound to continue to occur as long as nuclear power is in use, the public became leery about accepting nuclear power as an alternative energy source, particularly in their surrounding communities. In response, industries' risk communication strategies attempted to change this mindset and promote nuclear power as a safe, environmentally friendly choice for the world's energy needs. Attempts failed to strike a proper balance between concern and fear, and the inadequate use of language is largely responsible.

The business and regulatory communities and their public relations professionals had many options but selected some poorly conceived and executed strategies. For example, one strategy involved oversimplifying the language. Presumably, communication based on simplistic language would ease the public's understanding of a technical subject. Of course, this is true only when simple language can communicate the true risks effectively. Also, oversimplification may serve only to mask actual risks. Using simplistic language, public relations experts tended to have made nuclear power risks seem less significant.

Purposeful obfuscation was another tactic. The public relations officer of Pacific Gas and Electric proposed that industry spokesmen eliminate images and language that might work against them. He recommended that the Atomic Energy Commission (AEC) cancel a study on reactor accidents that could be used by antinuclear activists and that firms do "some semantic soul searching" to eliminate objectionable language: "palatable synonyms for scare words such as 'hazard' or 'criticality''' would facilitate public understanding of nuclear energy. Thus, nuclear plant sites became 'nuclear parks' and accidents became 'normal aberrations' (Nelkin 1987, p. 146).

Nuclear power risk communicators also used doublespeak and it led to some increasing public support. Ethical issues aside, the communication did achieve some of its goals. Eventually, limitations to the use of doublespeak were apparent. The public became desensitized to the 'more palatable' terminology. Attempting to find novel metaphors for doublespeak to relay the risks (or lack thereof) to the public became an enormous challenge. The public seemed to tire of one catch phrase, and the communicators were on the chase again for another appealing metaphor. Each subsequent generalization became less effective.

Nonetheless, the public seems to feel more secure in its level of knowledge with simplified information. Its perspective, based on a two-dimensional representation of reality often fails to engage the debate. Consequently, when consensus is forged, it comes through few discriminating channels and is fragile.

There is the obverse, a second problem for communicators. Communication through complexity makes understanding appreciably more difficult to achieve. Discussions about the risks associated with nuclear power generation can center on highly technical issues which few members of the public are familiar with. Metzler singled out technical jargon as a formidable obstacle to communicating risk.

Furthermore, there is evidence that technical and scientific jargon is counterproductive in risk communication for the majority of the public. The information must be unpacked into terms that the specific audience will understand. Typically this means explaining the risks in terms of how they directly affect those involved, such as that a worker has a 10% chance of being injured while performing a certain task. If people do not understand risk information, they can't make responsible decisions and will act on fear.

Add the observation that excessive use of acronyms, mathematical equations, and field terminology may also lock the public out of the debate. Not only are the concepts difficult to grasp, a third obstacle of risk language needs to be considered: some of the public may be unable to decipher meaning from the rhetoric itself. Numbers presented a unique problem in the nuclear power field. Science uses a plethora of numbers in its reports and assessments. Communication suffers because "most people find very large and very small numbers difficult to grasp" (Shortland & Gregory 1990, p. 87). For example, it is as difficult to imagine a 1 in 230,000,000 chance of electrocution as it is to imagine a .00000000007 (7×10^{-11}) chance of it. Risk is particularly susceptible to this type of reporting. Risks are frequently expressed in numbers or probabilities.

Finally, science and technology has a language of its own. Though confounding for anyone without scientific and technological training and expertise, its precision serves the technical community very well. Unfortunately, this level of specialization has marginalized a preponderant fraction of the population and they are at risk. By refusing "to integrate the scientific culture into the understanding [of the non-scientific one]... [t]he effect has been to spread misconceptions about science among the non-scientific public and has inhibited the full realization of science as a human institution" (MAST 1989, p. 26).

Learning from the case of nuclear fission power generation, risk communication in nanotechnology must use its resources carefully to reject oversimplification and technical jargon. Risk communication must be careful to avoid one excess in favor of another equally unfavorable excess. Since language is vital to express any concept, it is important to recognize the strengths of using appropriate language in relaying difficult concepts to the public and the weaknesses of using overly simplistic or technical language. Both seem to increase confusion, resentment, and may lead to rejection of bona fide desirable policies.

Though risk and crisis communication do examine some of the variables coupled with catastrophes, little scholarship examines less provocative scenarios. When it does, very little critical scholarship goes beyond ubiquitous computing or the enveloping nature of the Internet and its hypertextuality. While it may be true that your microwave oven or cell phone has changed your life, few scholars have detailed the rhetorical character of the changes, hence this project that draws on the history of domestic nuclear fission energy generation and the introduction of genetically modified foods.

Since risk is a prominent theme in discussions regarding nanotechnology, it is important that communicators recognize the role played by communication in alleviating or propounding public fears about new technologies. This will prove to be especially true regarding nanotechnology.

The MAST project reported its conclusions on risk perception of nanotechnology.

First, "technologies or activities that are familiar, well understood, controllable, or provide clear benefits are perceived as less risky than similar activities that are unfamiliar, poorly understood, uncontrollable, or without benefits to offset the risks" (MAST 1989, p. 10). Nanotechnology clearly belongs to the second category.

Second, "risk perception is also colored by the ethical complications that may be entailed in deploying a new technology. If it is likely to exacerbate differences between rich and poor, or to raise difficult questions about life and death, people will perceive it as less desirable" (MAST 1989, p. 10). With the economic and metaphysical implications of nanotechnology, the public may exaggerate risks.

Third, "when risks are exotic, difficult to understand, and very difficult to calculate while benefits are diffuse and unclear, the public is likely to interpret the risks as unacceptable" (MAST 1989, p. 59). The speculative nature of nanotechnology and its substantial dark side makes it a serious candidate for inappropriate risk assessment.

8. Framing the Public Sphere Issues

Scott Montgomery and Steve Fuller have led the pack in discussing public sphere related concerns associated with the rhetoric of science. Scott Montgomery made two substantive criticisms of science and technology speak. First, he indicted traditional science discourse as "roughly performative".

> Scientific information is conceived in and through a discourse that has undergone tremendous compression; it is a language that, over time, has been made super heavy by modes of short-hand condensation, substitution, fusional reduction, and by the elimination of any lighter, non-technical gestures of speech. (Montgomery 1989, p. 48)

Illustration and imagery are not being used to illuminate complex demonstrations. The audience has shrunken to an expert few. Anyone straining to decode scientific messages is left ill equipped and underinformed. As modes of shorthand become more prevalent, discourse becomes more and more privatized.

Second, Montgomery extended his claim by complaining that scientific discourse has actually become increasingly jargonized.

> If, as some maintain, contemporary science has become more "subjectified" than in previous decades, less dependent on the mythology of the "detached observer" and more willing to admit the truth of "probable knowledge", its voice has on the whole continued to travel the opposite road, becoming still more jargon-filled, less expressive, less allowing overt references outside itself. (Montgomery 1989, p. 53)

At some point, the jargon so privatizes the discourse that the audience becomes discounted. Viable claims tend to go unheard, incorrect claims unrebutted, implausible claims unfalsified, and outrageous claims mediated as events.

As a result of government regulation, rhetors in science and technology have been compelled to speak to the public. Though they are speaking more, the settings in which they speak continue to marginalize the public from the decision making process.

Steve Fuller explained this phenomenon in his 1993 book. Fuller distinguishes between prolescience and plebiscience. He blames this distinction on a "mutation of representative democracy [into] corporatism" (Fuller 1993, p. xviii). Fuller advocates science and technologies studies (STS) as a way to check corporate decision-making. To help characterize the status quo as opposed to one legitimized by citizen-consumer input, he bifurcated science policy into the two approaches.[2]

Supporting Feyerabend's perspectives whereby "the democratization of science is simply the reflexive application of the scientific ethos of free inquiry to science itself" (Fuller 1993, p. 283 & Feyerabend 1975), Fuller seems to feel "research agendas and funding requests [should] have to be justified to a board of non experts, not simply a panel of experts" (Fuller 1993, p. xviii). Those non-experts are citizen-consumers and Fuller assumes they will use free inquiry to resolve implications of science and technology.[3]

Sagan warns scientists against keeping science generally incomprehensible for citizen-consumers. "This is a prescription for disaster. We might get away with it for a while, but sooner or later, this combustible mixture of ignorance and power is going to blow up in our faces" (Sagan 1995, p. 26). He argues our global civilization is integrated into science and technology as well as the reverse. In turn, it is beginning to seem as if political decisions and scientific ones are more difficulty to separate. Popular support will become a co-requisite of science decision making especially as resources for expensive and exotic scientific investigations become more troublesome to find. It seems insolent to presume the public will continue to support science and technology policy just because scientists told them to. Witness what recently happened to the Texas Supercollider project.

Since there are powerful reasons to broaden the decision making population to include citizen-consumers, those interested in foresight and specific policy making options have a special obligation to make participation as open as possible. The citizen-consumer will need to learn about governing, and as issues become especially complex, they may even need to develop special fields of expertise that might have seemed esoteric and irrelevant before. While there is a reciprocal duty on the part of the citizen-consumer to strive to understand, it is very easy for the technoliterate to place ideas, concepts, and issues beyond their reach. For example, while discipline specific terminology is often obscure, it is further complicated by terminology associated with methodologies. While anyone can learn to understand the terminology of meteorology – high pressure, temperature inversion etc., this is not sufficient when these terms are buried under a blanket of jargon like multi-variate analysis, multiple regression, etc.

9. C. P. Snow and a Third Culture

C. P. Snow portrayed twentieth-century British and, by filiality, American intelligentsia, stratified into two "cultures": literary and scientified (Snow 1963). Snow blamed the resultant "gulf of mutual incomprehension between scientists and humanists largely on the refusal of humanists to integrate the scientific culture into their understanding" (MAST 1989, p. 26). John Brockman took Snow's second essay on culture ("A Second Look") and suggested that a third culture has recently begun to emerge that is somewhat unlike Snow's vision. Whereby Snow felt the "third culture" would involve "literary intellectuals ... on speaking terms with the scientists" (Brockman 1992, p. 16), Brockman says this is not the case but that "[s]cientists are communicating directly to the general public" (Brockman 1992, p. 16).

> The third culture consists only of those scientists and others who reside in the empirical world, who through their work and expository writing are taking the place of the traditional intellectuals and media in rendering visible the deeper meanings of our lives, redefining who and what we are in terms of our own species, the planet, the biosphere, and the cosmos. (Brockman 1992, p. 16)

Brockman believes "in the past few years, the playing field of American intellectual life has shifted, and the traditional intellectual has become increasingly marginalized" (Brockman 1995, p. 17). While traditional intellectuals bemoan this trend, it suggests a very intriguing phenomenon: "The emergence of this third-culture activity is evidence that many people have a great intellectual hunger for new and important ideas and are willing to make the effort to educate themselves" (Brockman 1995, p. 18). Rebutting elitists' claim that the public is naive and disinterested, we continue to see "scientific topics receiving prominent play in newspapers and magazines over the past several years including ... nanotechnology" (Brockman 1995, p. 19).

Brockman includes Stephen Jay Gould, Freeman Dyson, Stephen Hawking, Richard Leakey and others on his roster of third culture intellectuals, a group he also calls "new public intellectuals". These are experts in science and technology who take their cases directly to citizen-consumers through their popular writing.

10. Challenge for Third Culture Intellectuals

This group needs to be distinguished from false pronouncers who are often technophobic. They tend to be very critical without necessarily being very informed. Scientific and technical information also comes from those critics whose expertise may be limited and whose agenda seems political in nature or merely attempts to capture publicity. Two especially pertinent illustrations should be sufficient: Mander and Rifkin.

Gerry Mander, a new age anti-industrialist, criticizes nanotechnology for its anti-spirituality in a book reminiscing about Amerindian value systems. He criticizes nanotechnologists by describing them as a group of thinkers who have no historical appreciation of the horrors of technological progress (Mander 1991).

> There is, in the whole nanotechnology movement, no political understanding, no spiritual understanding and no feeling for nature outside the human realm. But the real problem is not in their vision or their intent. It is in their world-view – the same techno utopian world view that has already come close to destroying the planet. These people have in fact already left the planet. (Dowie 1988, pp. 148-149)

The other critic worth mentioning is Jeremy Rifkin. He has taken on biotechnologists, ecologists, and meat eaters in some of his books. An avowed techno-heretic, he has his own Washington, D.C., foundation. His views on nanotechnology are equally pessimistic.

> The idea that we will be able to redesign the material of this planet to suit the anthropocentric caprices of a generation of scientists and technicians without doing harm to the delicate fabric that has developed over a billion years is beyond hubris. (Dowie 1988, p. 149)

As a rule, this group of critics engages in mudslinging and appeals to fear to attract attention. Unable to accommodate ideas other than their own, they attempt to discredit scientific claims by deferring to some greater power. For example, Mander defers to some cosmic spirituality and Rifkin uses anthropocentrism. It would be exceedingly unfortunate if citizen-consumers were forced to accommodate these technophobic and dystopian claims rather than scientific ones.

11. The Media Recedes from the Public Sphere

Traditionally, citizen-consumers have learned about science and technology through an interpretive medium, a college of scientific journalism. Though many journalists lay claim to membership, very few carry the experience, credentials, or both.

A major criticism of them is that science journalists simply lack zeal. Fuller argues "except in cases of scientific misbehavior sufficiently grave to worry Congress, journalists will often print watered down or mystified versions of a scientist's own press release, which ends up only increasing the public confidence in science without increasing its comprehension" (Fuller 1993, p. 234).

Journalists are not only underzealous, but their publishers are also underconcerned about accurate reportage. Citing Burnham, Fuller reports "the supermarket tabloids [remain] the public's primary source of information about the latest developments in science" (Fuller, 1993, p. 236, Burnham 1988). Journalists and publishers are driven by market considerations, selling copy. Though their motives may not be universally impeachable and suspect, they hardly advance the interest of accurately informing citizen-consumers.

While some journalists make a genuine effort to accurately report scientific claims, fighting for column space they must give their editors what they can sell. For example, when coverage is given to science, the sensational is often accentuated. Too often many scientific claims are reported before definitive burdens and standards of proof are met (cold fusion, for instance). Highly impatient readers tend to blame inconclusive results on bad science rather than premature reporting and outrageous overclaims.

Not only do science journalists devalue the time frame between theorizing and verification, but they also present issues in "winner-take-all contexts that turn on some crucial fact or event" (Fuller 1993, p. 235), promoting an overly simplistic model of causation. Furthermore, science journalists do not appreciate proof obligations associated with scientific claim making. "Moreover, the more provocative the theory under dispute, the more likely journalists will champion it, which often serves to shift the burden of proof onto the opponents..." (Fuller 1993, p. 235).

Finally, trying to balance their reporting, reporters tend to solicit respondents from a local college. These experts express opinions on claims about which they are often unprepared to make truly informed comments. This often leads to attacks on credibility, sometimes personality assaults, which leave readers with a view of scientific discourse as a schoolyard brawl.

12. Third Culture Intellectuals Enter the Public Sphere

The result: the majority of those writing in an attempt to bridge Snow's "two cultures" and to communicate with a scientifically unsophisticated audience write articles with flash, sparkle, pizzazz, but weak on information and insight. In response, third culture intellectuals have begun to avoid the science media altogether.

Traditional intellectual media played a vertical game: journalists wrote up and professors wrote down. This is an activity referred to as popularization. Today third-culture thinkers avoid the middleman [sic] and write their own books, much to the consternation of those people with a vested interest in preserving the status quo. Some scientists have seen that the best way to present their deepest and more serious thoughts to their most sophisticated colleagues is to express these thoughts in a manner that is accessible to the general intelligent reading public (Brockman 1992, p. 16).

Third culture intellectuals have begun to avail their writing to the more general readers markets. Luckily for them, readers have begun demanding more science related literature. There has emerged a thriving demand for their works. According to W. Daniel Hills, "People no longer have a view of the future stretching out even through their own lifetimes, much less through the lifetimes of their children. They realize that things are moving so fast that you can't really imagine the life your child is going to lead. That's never been true before, and it's clear the cause of that change and that discontinuity is science, somehow" (Brockman 1995, p. 26). Much like von Neumann, Vinge, Eder, and Ross' view of the singularity, the citizen-consumers recognize a compelling need to learn to survive, and "one way to do it is to read books by scientists" (Brockman 1995, p. 26).

The new public intellectuals are motivated to publish directly to citizen-consumers for two additional reasons.

First, they are often interdisciplinarians. Their fields of theorizing and reasoning are insufficiently distinct. Their ideas and claims "don't fit within the neat structures of their internal disciplines. Many of the scientists who write popular books do so because there are certain kinds of ideas that have absolutely no way of getting published within the scientific community" (Brockman 1995, p. 26). Their work seems outside a publication's usual fare – partially pertinent but not wholly so. Drexler made a very similar complaint regarding his own research.

The second reason: scientists have begun to understand that consensus building and outright support for their interests and fields are necessary co-requisites to their theories and findings in order to procure and sustain third party interest and backing for their research agenda.

Because science exists in a dialectical relationship within the broader society and culture, scientists must justify their pursuits to the political leaders and other persons who control essential resources (Moyer 1992, p. 8).

Popular support can move government as well as create and sustain demand for industrial products and services. Third culture scientists are marketing their ideas directly to citizen-consumers engendering support to help secure patronage on many different levels: public interest groups, foundations, university and college administrators, government agencies, and policy makers. Science has its lobbyists and third culture scientists contribute in their own way toward popularization of their projects. Brockman's observations are particularly true regarding nanotechnology.

13. Preliminary Observations: Communication about Nanotechnology

Teaching science is no small feat. Witness the popularity of more subjective or softer disciplines at America's colleges and universities. There is a simple reason why America has lagged in science and mathematics education: for most of us, it's difficult. Nevertheless, nanotech evangelists need to package this new technology in a language that most citizen-consumers can try to comprehend.

Drexler joined the ranks of third culture scientists by speaking directly to the public. He and his colleagues still remain a predominant source of information on nanotechnology for the general public. Hence, my primary criticism focuses on Drexler and The Foresight Institute (FI).

14. Case Study: Criticism of Foresight Institute Communication

FI's goal involves developing and supporting public consensus. "[T]oday, only the smallest fraction of the world's population is aware of the coming juggernaut, or even slightly prepared to cope with the kind of changes that it will bring in its wake" (Merkle 1993, p. 15). Merkle continued: "it just hasn't sunk in. The possibilities of rocketry didn't sink in to the good citizens of England until they found themselves on the receiving side of a barrage of V2's. The idea that washing your hands might be advantageous didn't sink into the medical profession until almost the turn of the century, despite the fact that Ignaz Semmelweiss demonstrated its value quite clearly in 1848" (Merkle 1993, p. 15).

We are slow to catch on. Applied nanotechnology "will change both the world in which we live and the assumptions we live by" (Merkle 1993, p. 15). Hence, FI's goals must include both educating citizen-consumers and empowering them with a sufficient understanding to develop and sustain a consensus, which will lead to informed and wise decision-making by the governmental and corporate barons of our technocratic state.

While they have had some triumphs, FI has not been very successful to date. Fault lies in many hands, some are personal, and some are systemic or organizational.

FI and its people remain diligent and persistent. Being outspoken about a speculative technology is also daunting. Weaker men and women would have backed off years ago. Despite some nasty personal attacks and ridicule, they continue to make their case known. The following criticisms are wholly constructive in intent. They are observations made by an outsider who greatly respects FI and its people.

15. Specific Concerns

First, access to FI material is difficult. Drexler's *Engines of Creation* can be found in many libraries and bookstores, *Unbounding the Future* is in bookstores, *Nanosystems* can be ordered from its publisher and it is slowly making it to university library shelves. While all three books are available from FI, FI's publications are less available. Initially, FB (*Foresight Background*) and FU (*Foresight Update*) were mostly unavailable except to a select group of members. Today, FU can be downloaded from the Rutgers archive of sci.nanotech and FI's web page.

Though FI attempts to disseminate information, they have closed down some conduits of information flow. Anecdotal support is found in a FU where in response to a request by a high school student for information on nanotechnology which he could use in interscholastic debates, FI answered: "We have prepared a package of materials for high school debaters." Furthermore, they responded, "[d]ue to the large number of debates (*sic*), we ask that a $4 donation accompany each request".

Though filling requests for information can be costly, it is imperative that information be circulated as freely and completely as possible. Creating barriers as simple and seemingly minor as a fee are counterproductive. In addition, to design a kit which provides only selective material is unnecessarily patronizing. This is especially problematical when we begin to understand that "[t]hese debaters, young men and women, will be tomorrow's leaders". If we keep these young people fully informed "when they design remedies for some of the problems confronting society in the 21st century, nanotechnology will, at least, receive a serious and fair discursive treatment" (Berube 1990, p. 6). The solution demands a more open market for information on nanotechnology, which may require more aggressive fundraising and grant solicitation and less discrimination.

Second, access to FI concepts is difficult. There are two reasons: First, what is nanotechnology? Less than two-thirds of the respondents to the MAST study could agree on a definition of nanotechnology; the remainder of the respondents in the project could not agree on the definition of one of the most important key terms of the survey (MAST 1989, p. 94). A recent bibliometric study demonstrated a similar dissonance (Porter & Cunningham 1995, pp. 12-15).

The prefix nano means a measurement of size. It appears when we approach submicron sizes.

Consider how the prefix has been used. For example, "[t]wo new companies making fine-grained materials are Nanophase Technologies and Nanodyne. Longevity magazine carried ads for NANO shampoo and NANO conditioner, containing a derivative of the anti-baldness agent minoxidil" (Drexler 1993, p. 9). A company, which markets medical diagnostics and biopharmaceutical arrays, is called Nanogen. It is attempting to combine molecular genetic, microelectronics and nanotechnology in product design ("Nanogen..." 1994, n.p.). Nanometrics, a decade old Silicon Valley company manufacturing semiconductor metrology equipment, "has nothing to do with molecular nanotechnology" (May 1995). Two pharmaceutical biotechnology firms, Vertex (VRTX) and Agouron (AGPH) are traded on NASDAQ and both claim they are developing pharmaceutical compounds atom-by-atom (Conover, 1995). Gryphon Services claims to be on the verge of marketing "nanoceutical" products, a synthesis of large, complex multifunctional molecules for a new generation of vaccine and gene therapy ("Gryphon Services..." 1996). On the other hand, Nanothinc (Foremski 1994b, p. 8) is about to base its whole business on the embryonic nanotechnology market (Smith 1994, p. C5) with products, services, and divisions like Nanotainment, a product and consulting division, and Nanoventures, an investment service.

The root word 'technology' describes everything from a flint axe to a 2 GHz processor. "Nanotechnology in the broader sense of nanoscale technology covers a diverse collection of activities, with varying relevance to this goal" (Smith 1994, p. C5). As Timothy May posted, "most uses of nano don't have anything to do with molecular nanotechnology" (May 1995).

> Confusion over terminology has led to substantial communication difficulties. For example, in the U.S. the term nanotechnology is beginning to be used by those doing submicron semiconductor work of all sorts. This makes it difficult to discern the goals and drives researchers to use the longer and more complex terms molecular nanotechnology and molecular manufacturing. (Peterson 1992b, p. 399)

Furthermore, this problem is aggravated by two additional observations. First, "truth be told, there was never any love lost between the micro and nano factions of the miniaturization fraternity" (Regis 1995, p. 237). Secondly, micromachinery may be irrelevant to mechanosynthesis nanotechnology.

One of the problems Drexler has confronted is simply one of naming and definition. He testified that "[n]anotechnology has become a buzzword, but if is often used to describe incremental improvements in existing semiconductor technologies, although of great value in their own right, they are of surprisingly little relevance to molecular nanotechnology" (Drexler 1992, p. 21). Drexler referenced those tiny machines, which are featured occasionally in some of our newsweeklies. He concluded that as nanotechnology, "[m]icromachine research, often confused with nanotechnology in the popular press, is even less relevant" (Drexler 1992, p. 21). Merkle characterizes the misappropriation of the term 'nanotechnology' as a "turf war". He explained:

> "Nanotechnology" is a term, which has an aura of excitement and great promise. Much if this aura was created by Drexler's adoption of the term and its association with molecular manufacturing. As a consequence, many researchers wish to adopt a definition of "nanotechnology" which includes their own work. An unfortunate consequence of this is that the unqualified term "nanotechnology" has come to mean very little. (Merkle 1996)

The confusion over the nanotechnology label is further confounding because "[t]his degree of overlap between nanolithography and micromachines, on the one hand, and molecular nanotechnology, on the other hand, appears to be remarkably slight, even though those subjects have commonly been confused in the popular press" (Drexler 1992, p. 30). Add that the product of both processes might very well be indistinguishable. A nanoscale machine whether chiseled to size or built from the atom up remains a nanoscale machine.

Nanotechnology means different things to different people. To Eric Drexler it is an extraordinary vision of machines as small as molecules making things an atom at a time. To many others, it is a more prosaic, though still impressive vision of electronic circuits scaled down from the size of a micron, to that of a nanometer, a thousand times smaller still ("Dotty" 1993, p. 89).

Taneguchi and Drexler use the word "nanotechnology" differently and when writers link together citations from papers, articles and books, they often commit the so-called term shift fallacy whereby meaning becomes obfuscated because descriptions of unlike things labeled the same are inaccurately juxtaposed. No wonder time frames for the arrival of assemblers and nanotechnology are so variable.

> Does nanotechnology now exist? Has the revolution arrived? If so, then the nanotechnology revolution seems to be a dud. Where are the molecular machines? Where are the desktop manufacturing systems? Where are the nanocomputers, the cell repair machines, and the era of abundance? Few in the newly mustered army of nanotechnology researchers aim at such goals. It would seem that there [has] been a profound miscalculation – unless, that is, there has been a more prosaic modification in the use of words. ("Dotty" 1993, p. 89)

Drexler exhibits much of the frustration of the experienced wordsmith and image-maker. Any public relations acolyte would grant two truisms: (1) make certain you are accurately describing what you are pushing, and (2) it is easier to create an image than to recreate it.

Drexler discusses dry 'bottom-up' molecular mechanosynthesis nanotechnology manufacturing. Unfortunately, this term is seriously confusing. Drexler finds this term and others like it "bulky and awkward enough to retain a distinct meaning" ("Dotty" 1993, p. 89). He understands that by reducing it to the single word 'nanotechnology' it would feed the term shift fallacy, which is plaguing much non-technical discussion of this field. Drexler fields as many questions about definitions as about feasibility, and he readily admits that naming and labeling is an enormous difficulty when trying to generate consensus.

Consider this illustration. The nanotechnology that yields the magnet particles described in *Science News* (Pennisi 1992, p. 20) works by oxidizing ions that have been loaded into an ion exchange resin used commercially in water softeners. This is, literally, nanotechnology because the resulting iron oxide particles are only 2 to 10 nanometers across, containing mere thousands of atoms. Of course, along this line of argument, producing cigarette smoke would also be nanotechnology (Drexler 1993, p. 9).

It's not all bad news. It may be somewhat correct to claim that awkward descriptions might discourage term shifting. Nevertheless, as it is universally true that the more one speaks and writes the more likely one is to contradict oneself, so it is exceedingly difficult to erase the misunderstanding fostered by Drexler and FI's earlier work in the late eighties.

So where's the good news? The good news is that the confusion "is a sign of progress. Researchers in chemistry, molecular biology, material sciences, and so forth, have worked at the nanoscale for many years; the advent of a new, unified perspective, and with it an understanding of longer-term goals for the field" (Drexler 1993, p. 9). If FI sees itself as a macro-organization umbrellaing the field of nanotechnology, then Drexler's save is legitimate. On other hand, if its purpose is to foster understanding and develop public and technical consensus, the use of the vague term 'nanotechnology' to describe molecular nanotechnology based on mechanosynthesis is self-defeating and confusing.

A second major problem with access: nanotechnology is still steeped in technobabble. This has implications on the two levels of scientists and engineers, and of the citizen-consumers or the public world.

Ostman made an interesting observation in 1994. "Lack of awareness even amongst the technical community is still probably the greatest impediment toward a more robust pursuit of nanotech development" (Ostman 1994, p. 558). Drexler and the FI are trying to keep some of the scientific and technical community informed with their conferences and Web Enhancement Project. These efforts are laudable but much remains to the done.

The challenge is further compounded by the interdisciplinary nature of nanotechnology. This demands the special rhetoric that Steve Fuller dubbed interpenetrative. He argues that a knowledge policy reaching across disciplines must address the new epistemic standards created to make interdisciplinary exchanges meaningful. Fuller complains interdisciplinary discourses usually "mutate without replacing some already existing fields. Thus, they merely amplify, not resolve, the level of babble in the academy" (Fuller 1993, p. 40). He further grumbled that pluralists are not the answer either.

> Given the exigencies of our epistemic situation, pluralists hardly help matters by magnanimously asserting that anyone can enter the epistemic arena who is willing to abide by a few procedural rules of argument that enable rival perspectives to remain intact and mutually respectful at the end of the day. (Fuller 1993, p. 40)

Fuller asserts that the separate disciplines retain much, if not most, of the language and ideas which help define their uniqueness such that interdisciplinary communication is seriously challenged. Prestige and stature considerations catalyze a defensive epistemic, which appears cooperative yet stymies interchange by forcing any depthful and layered exchange to use the babble specific to the fields being addressed.

Finally, dominant discussants emerge either because they arrived early or because they involve better rhetors. They may, intentionally or unintentionally, establish a vocabulary, grammar, rules of argument, even tools of conviviality, which prevent newcomers from making their message known. Even if expressed, it seldom is likely to become the center of attention unless it is remarkable prescient and insightful.

The public world is challenged as well. Babble on this level convinces the public or the citizen-consumer that the scientific community has little intention to communicate with them.

Technobabble is a pervasive phenomenon in debates over science and engineering. Nanotechnology is not immune from technobabble, and it may be an unfortunate and an inescapable problem. For example, when FU reports advances that may be significant in terms of nanotechnology research and development, it is forced to use the terminology of science. This is especially true since Jeffrey Soreff took over the "Recent trends" column in FU. It is apparent that Russell Mills and Soreff, the current writer, addressed very different audiences. This alphabet soup of acronyms makes communication between science and the layperson more difficult. Though on some levels, it might make communication between scientists easier.

Drexler and Peterson wrote: "[i]f our future will include nanotechnology, it would be useful to understand what it can do, so that we can make sensible plans for our families, careers, companies and society" (Drexler, Peterson & Pergamit 1990, p. 38). Unfortunately, FI and others don't seem to fully appreciate the importance of popularization. Referencing Burnham, Drexler and Peterson summarized the problem nicely. "Today, the culture of sciences takes a dim view of popularization. If you can write in plain English, this taken as evidence that you can't do math, and vice verse" (Drexler, Peterson & Pergamit, 1990, p. 36, Burnham 1988).

James Dinkelacker provided me with a vivid illustration of this problem. Criticizing a very early draft of this manuscript, he made the following comment.

> To those of us who are faced with the challenge of actually communicating this information, instead of the luxury of communicating about it, professional language is a necessity. Some ideas can only be expressed pragmatically in equation form; and if a person doesn't understand the basics of a sp3 carbon bond, or he [isn't] familiar with kt as a concept, it would take tens (if not hundreds) of hours to bring him/her up to speed. Why penalize the many thousands who took their chemistry courses in high school, and did their homework? I reject the notion that either you or I, with our advanced degrees, can truly judge what is "accessible" to the lay public. (Dinkelacker 1991, n.p.)

The tenor of his remarks suggested that there is an expertise barrier, which might be impenetrable to the public. Though I doubt that he embraced the apparent tenor of his remarks, this insipid form of technoelitism must be rejected.

> The reality is that technology has created a huge gap between the techno-literates and the techno-illiterates, between those who can ride the technological wave to financial awards and those who must remain outside its direct influence. This reality flies in the face of society's ideals of equal voices, equal opportunity, equal influence, and equal access. While the reality-ideality split has always existed, the advent of high-tech instrumentation has accelerated the pace of dislocation. (Hey 1991, p. 51)

This reality-ideality split will be substantially aggravated especially during the early transition period of a nanotech civilization. In order to enable techno-illiterates participation in that culture, we must begin to prepare them. Peterson seems to understand the germ of this potential problem.

> Educating the public is very important. Eventually, there are going to be political issues that arise. They haven't arisen yet, but they're inevitable, and to have those decisions made correctly – or at least have them not made incorrectly – you need an educated public, and we're nowhere near there yet. (Peterson 1992a, p. 12)

In response, Drexler and FI have made some attempts to simplify many of the concepts associated with nanotechnology. Drexler's greatest achievement might have been *Engines of Creation*. As I wrote in 1990, "*Engines* was readable by everyone and only misunderstandable by those who refused to open their minds.... More important, its explicative style reads as easily as fiction" (Berube 1990, p. 6). This very quality may account for the fact that nanotechnology has become the subject of much current science fiction. This is understandable because any new idea is bound to solicit unexpected conjecture.

However, the third major problem associated with access to FI concepts is not a function of how others have conjectured about nanotechnology, but rather how Drexler and FI have conjectured about it themselves. Traditionally, science and technology rhetoric includes occasional attempts to explain using imagery of all sorts. Straining to familiarize a deep scientific observation or discovery, rhetors attempt to use popular terminology. Most often the audience gets carnival facts, banal awareness, storybook imagery, military simile, and sports references (Montgomery 1989, p. 68). Metaphors are complex language devices and poorly wielded by inexperienced communicators. The rhetors of nanotechnology end up receiving a failing grade for effort and product.

For example, Drexler and FI's efforts to oversimplify nanotechnology have led to similes which function to trivialize nanotechnology and stoke the ovens of pseudo-scientific conjecture. Here are a few illustrations: Drexler referred to the unlikely uncontrolled replication scenario as "gray goo". Hapgood and others picked up the phrase and used it as a central focus for their journalism: rich in fantasy and poor in fact. Even Congress' OTA report includes a reference to the "gray goo" metaphor (OTA 1991, p. 20).

Also, in his 1989 OMNI interview Drexler discussed the "cabinet beast", that is, a machine from which you could slice nanotechnologically fabricated meats (Drexler 1989b). This image enabled the interviewer to ask: "Doesn't the so-called meat machine enable you to shovel in some straw and dirt and have a steak pop out?" Rudy Rucker describes a tongue-in-cheek dialogue.

> "You done building that roast beef out of dirt yet, Bob?"
> "Ten molecules down, to the twenty-sixth power to go." (Rucker 1993, p. 95)

Here's another. In an early *Foresight Background*, Drexler used a simile as he tried to define the difference between a bacterium with an *Engines*-style nanomachine. It is "like confusing a rat with a radio-controlled model car" (Drexler undated, p. 3). Not very elucidating.

Though this imagery may seem innocuous, it stokes ridicule. Nanotechnology is sufficiently astounding without attaching images like those mentioned above. Reporting on the

1992 nanotechnology conference, Mike Langberg wrote that "proponents of nanotechnology are making such grandiose claims that the Palo Alto meeting sometimes appeared at risk of sliding into science fiction". He tells an anecdote about Minsky's luncheon speech. Rhapsodizing on nanotechnology and its creative applications, Minsky "looked at the audience and paused. 'I don't want to go on like that, because I'll scare the financial people away'" (Landberg 1993, p. B7).

Practices like these make FI concepts more difficult to assess. The solution may involve reducing techno-babble and simultaneously reducing fantastic similes.

A fourth major difficulty: access to FI ideas is difficult. This is primarily because FI has failed to endorse any evaluative matrix by which complex nanotechnological issues may be analyzed, if not resolved.

Again, there are two challenges: communicating among scientists and engineers and communicating with the public. Without a common solution to both these problems, the challenges must be met with different tactics.

First, there is the challenge of communication among scientists and engineers. The MAST survey in 1989 included experts from many disciplines: "biological sciences; mechanical, electrical, and chemical engineering; pharmacology; computer sciences and artificial intelligence; robotics; and others." 'Others' was a broad grouping and included a list of researchers who might impact on the future of molecular nanotechnology. They were involved in:

- Macromolecular design and folding
- Self-assembly methods
- Catalysis (inorganic, enzyme and other)
- Dendrimers, fullerenes, and other novel chemical structures
- Bioenergetics, nanobatteries, and ultrasound driven chemistry
- Semiconductor-organic/biological interfaces
- Miniaturization and massive parallelism of SFM
- Molecular modeling tools (Nelson & Shipbaugh 1995, p. xi).

MAST assumed these disciplines as likely to "draw on and effect" discoveries involving molecular and atomic scale technologies (MAST 1989, p. 1). A concern expressed in the MAST report was "the difficulty encountered by researchers in the various fields in finding out about relevant discoveries in other fields" (MAST 1989, p. 1). In other words, chemists need an easier way to learn what protein engineering is up to.

To FI's credit, it has done an excellent job of networking interested researchers across many fields. We are near to reaching the point where anyone with an interest can find out who is doing what in the field of nanotechnology. Vocabulary and conceptual barriers will slowly fall until only the researchers unwilling to make the effort will be incognizant of developments in another field impacting their own research agenda.

Second: communicating between technologists and citizen-consumers remains a challenge. Since nanotechnology seems to affect everyone to some degree, and since deciding what is desirable should not be left to the scientists and engineers exclusively, we need to reach out to a large base for support and input. This seems especially true when the vanguard might be consortia of governments and industries rather than a single state, national or even transnational corporate organization. What we need is new organizational thinking to help generate events which can then be tested in simulations.

16. Some Concluding Remarks

Unless an affirmative effort is made to incorporate citizen-consumers into the decision-making process, the reality-ideality split will worsen. What too many of us sometimes for-get is that absent extensive efforts to educate the citizen-consumer, pseudo-technoliterates will people the ranks of both techno-utopians and technophobes. A failure to speak to the citizen-consumers risks fueling pervasive popular misunderstanding. Such misunderstanding could, in turn, produce formidable resistance as pseudo-technoliterates become prominent and ridicule nanotechnology.

People listen to Mander, Rifkin and even Limbaugh. In turn, their works become rallying points for technophobic dissent.

On the other hand, if those who understand nanotechnology educate the citizen-consumers, they may be able to mitigate many of the effects outlined above. Dinkelacker modified his earlier comments to me a few months later.

> Advances in molecular research are accelerating, and thorough control over the structure of matter appears to be imminent. Clearly, it's vitally important for everyone to be aware of the potentials of these oncoming technologies. It is only through communication and education that the public and technical communities can become knowledgeable such that they are prepared to make informed decisions. (Dinkelacker, 1992b)

In the same letter, he offered an additional goal of the FI as "working to communicate with people about the prospects of nanotechnology and molecular manufacturing so that society can be bettered prepared" (Dinkelacker 1992b). The most significant by-product might be an army of enlightened citizen-consumers who embrace rather than ignore or reject the nanotech civilization. Indeed, Milbrath has suggested, "[o]ne of the best ways to work for planetary policies is to try to help people all over the world develop an understanding that these are questions that require consensus" (Milbrath 1992b, p. 316).

This is a massive project, as is my scholarship on the subject. While much of it is dedicated to a careful study of Drexler and the Foresight Institute, it also includes the rhetoric of policymakers, national laboratories, university NanoCenters, private corporations, and venture capitalists. A fuller account therefore must go beyond this article (Berube 2005).

Notes

1. http://www2.ncsu.edu/ncsu/univ_relations/crisis.html.
2. Prolescience characterizes the philosophy that "knowledge production should proceed only insofar as public involvement is possible" (Fuller 1993, p. xviii). Plebiscience involves the public only when adverse consequences are likely and then it involves only the directly impacted community. Fuller views prolescience "as an implicit challenge to many of the elitist assumptions of plebiscience" (Fuller 1993, p. xviii). Prolescience is characteristic of hyperdemocracy which is defined by a far greater emphasis on initiative and referendum, that is, two vehicles of change which even our elitist founding fathers considered sufficiently worthwhile to incorporate into our governing charters.
3. Scientists can account for their behavior and research agenda. "It may be inconvenient for scientists to make sense of their activities to a larger audience, but they are not precluded from doing so mainly because of the work they do" (Fuller 1993, p. 283). Scientists are sufficiently competent to compose grand proposals to fund their research agenda. Oftentimes, grant non-scientists make allocations. As such, scientists have become sufficiently adept at answering all questions, scientific and otherwise. They testify before Congress, are interviewed on morning talks shows, and even do book tours.

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