"Societal and Ethical Implications of Nanotechnology": Meanings, Interest Groups, and Social Dynamics

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Introduction

Along with the first visionary ideas of nanotechnology, ideas about its possible cultural and social impacts were articulated (Drexler 1986). When the US National Nanotechnology Initiative (NNI) was launched in 2000, the program included from the very beginning funding for "societal and ethical implications of nanotechnology". Engineers and policy makers seem to have learned from the past, notably from the consumer disaster with genetically modified organism and from debates about the Human Genome Project, that ethical and sociological reflection should accompany and not follow technological research and development. And thus they invite the cultural and social sciences to help analyze and mediate possible conflicts. That appears to be a great opportunity for cultural and social scientists to engage in partnership models with scientists and engineers such that both groups can immensely benefit from each other, for the overall benefit of the society, provided that both groups learn from each other and respect their different perspectives, goals, and problem approaches.

At the present state, however, cultural and social scientists seeking to partner with scientists and engineers to work on "societal and ethical implications of nanotechnology" are faced with two problems that are caused by nanotechnology's immaturity. Nanotechnology's immaturity has a conceptual and a social aspect that are both relevant here. Conceptually, the lack of meaningful definitions of nanotechnology has led to the current situation that in almost all the science and engineering disciplines researchers relabel their cutting-edge work "nano", without having much new in common and without showing any remarkable degree of interdisciplinarity (Schummer 2004a/b). In such a situation of hype, cultural and social scientists may have difficulties to decide what research projects should really count as "nano", such that their choices might depend rather on mass media coverage and visionary promises than on the particularities of the actual research project. The prevailing articulation of nanotechnology in visionary terms is the social aspect of nanotechnology's immaturity, which brings about the second, more important problem.

Nanotechnology is not only primarily articulated in visionary terms, these visions also appear to be visions about "societal and ethical implications" of nanotechnology. Apart from scientists and engineers, policy makers, science managers, business people, journalists, transhumanists, and science fiction authors all talk about “societal and ethical implications” of nanotechnology. They all seem to have already strong opinions about what the “societal and ethical implications” of nanotechnology will be, that it will radically change society, bring about a new industrial revolution, can enable anything from immortality and paradise on earth to the extinction of the human race. How could cultural and social scientists, who have no expertise in fortune telling and are, instead, bound to their scholarly standards, contribute to a debate that is dominated by such bizarre visions? How could their academic reflections compete with ideas about the “societal and ethical implications” of nanotechnology that are meant to stir the innermost hopes and fears of people? It seems that, because of nanotechnology’s immaturity, it is either too early or too late for cultural and social scientists to become engaged in the debate.

However, the debate as such is currently the strongest, if not the only, impact nanotechnology has on society and culture—perhaps the strongest it will ever have? Furthermore, current ideas of nanotechnology, including hopes and fears articulated in visions about “societal and ethical implications”, have an impact on decisions on the current and future directions of nanoscale research and development, such that the dynamics of the debate determines the future shape of nanotechnology, including its future “societal and ethical implications”. This opens up an important opportunity for cultural and social scientists without joining the visionary debate. By studying the debate on “societal and ethical implications” of nanotechnology with their own methods, they can make important contributions to the understanding of factors that impact the current and future “societal and ethical implications” of nanotechnology. Whether such an understanding of the debate will have and impact on the debate is yet to be seen though.

My first contribution in this paper is an analysis of the various meanings of “societal and ethical implications”, with focus on the US. We will see that the major groups engaged in the debate have quite different meanings. Since these groups have more or less strong interests in nanotechnology that determine their meanings, I point out these interests as well. To complement the bird’s eye view, I also include my own group, that of cultural and social scientists, their specific interests, and their sophisticated meanings. Understanding the different meanings may help avoid misunderstandings, such as when, for instance, politicians ask cultural and social scientists to study “societal and ethical implications”. Following up the semantic analysis, I describe the mutual impacts of these meanings among the interest groups of the debate, i.e. how one group influences the meaning of “societal and ethical implications” of the other. The results are used to identify the semantic mediators and the semantic leaders, i.e. the groups whose meanings dominate the debate, and the formation of semantic alliances. From that I finally draw some more speculative conclusions on some of the likely "societal and ethical implications" of nanotechnology in the near future.

Interest Groups and their Meanings of "Societal and Ethical Implications of Nanotechnology"

Science Fiction Authors

Science fiction writers are the most professional group engaged in writing visions on the impacts of technology on culture and society, and many are used to making a living out of that.

Within the genre of science fiction, nano-science fiction is certainly one of the most flourishing fields nowadays. An online bibliography on Nanotechnology in Science Fiction lists 189 books, novels and anthologies, published between the mid-1980s and November 2003 in the English language only (Napier 2004). Milburn has identified many nano-science fiction stories in the 1940s and 1950s and argues that these stories already inspired Richard Feynman's 1959 visionary speech "There is plenty of room at the bottom", which later became the posthumous founding myth of nanotechnology (Milburn 2002). Invisibly small devices or the manipulation of the "ultimate building blocks of nature" have been a favorite topic ever since the genre of science fiction emerged and appear throughout the works of Jules Verne and H.G. Wells. In addition, 'manipulating-nature' was the pivotal theme in all the 19th-century 'mad scientist' stories, which in turn go back to medieval and early modern satires of alchemy (Schummer, forthcoming). Thus, the vagueness of nanotechnology definitions is passed on to the vagueness of what is nano-science fiction.

Unlike the name suggests, today's science fiction stories are hardly about fictional science and rarely about research and development of fictional technologies, but mainly about the use of fictional technologies in social contexts. As any other stories, they focus on characters, their thoughts, emotions, and transformations, and their interactions and social contexts, which are more or less radically modified by fictional technologies (Landon 1997). And unlike the visionary engineers who made nanotechnology prominent by making epistemic claims about a likely future, science fiction authors explicitly declare that their works are invented narratives, such that both text types are linguistically well distinguishable and still have quite separated readerships, despite border-crossing authors who increasingly blur the boundary (Schummer 2004c).

Although the primary goal of science fiction is entertainment, the genre is frequently divided up according to different moral messages expressed by optimistic or pessimistic prospects of technology for society. A utopian branch, frequently related to Jules Verne, would celebrate the positive prospects of technology for society and a distopian branch, frequently related to H.G. Wells, would warn of the negative prospects of technology for society. While the distinction between Verne and Wells is certainly more complex, it is true that there were very optimistic science fiction stories, particularly in the early 20th century in the US (Hirsch 1957-58), and that there is a distopian tradition (e.g. Orwell's *1984*) and a tradition of horror stories, which goes back to the 19th-century 'mad scientist' stories. However, there are also traditions of mystery, fantasy, detective and crime thrillers that overlap with science fiction and do not fit the dichotomy.

Many of the stories that are today called nano-science fiction, including for instance Neal Stephenson's *The Diamond Age* (1995), also run under the insider labels of 'Cyberpunk' and 'Postcyberpunk', depending on whether they focus on a radically computerized society or additionally employ fictional biotechnology.[1] The nihilistic undertone and the focus on human alienation might qualify them as distopia, but this is frequently balanced by a fascination for the visionary techno-world. As Brooks Landon (2004) has argued, even if the fictional nanotechnologies threaten the current condition of humanity, the stories frequently provide prospects of transcendence "in the numinous form of Bear's noosphere and Di Filippo's URB or in the form of enhanced and expanded consciousness found in nanotechnology narratives by Goonan, McCarthy, McDonald, and Reynolds". Instead of conveying a simple moral message, it is rather up to readers to make their own positive or negative judgment on the fictional technology's impacts on society. While many readers might feel uncomfortable with such visions, Cyberpunk has, as a matter of fact, inspired many, if not all, visions of transhumanist utopia.

Few nano-science fiction stories directly prompt moral questions about technology. An example is Michael Flynn's *Nanotech Chronicles* (1991). However, Flynn (particularly in "The Washer at the Ford"), draws his readers into a network of different moral positions and arguments, illuminates various positive and negative impacts of fictional bionanotechnology on society, such that readers learn more about the complexity of moral issues and dilemmas, rather than receiving simple answers or moral messages (Berne & Schummer, unpublished). There are exceptional cases, however, like Michael Crichton's *Prey* (2002) that employs Drexler's gray goo fiction. In the tradition of 19th-century mad scientist horror stories, Crichton retells the old fable of scientists (here, software engineers) who loose control over their work to the extent that they are threatened and finally controlled by their own creations.

For the majority of nano-science fiction authors, "societal and ethical implications of nanotechnology" is an experimental field of composing social contexts with visionary technologies (mostly computer technology) that more or less radically change humans and society, from using new tools to achieving a state of transcendence. Apart from making a living and from entertaining readers, their major interest seems to be to make readers think about general social and moral issues, about the place of technology in society, and about radical change, without providing simple answers or moral messages. Many have taken visionary ideas from Eric Drexler and many have in turn inspired transhumanism.

Scientists

Research without "societal implication" is equivalent to the much-denounced research in the "ivory tower" for which funding has drastically been cut. Since the costs of scientific research have tremendously increased during the past 50 years, due to the growing standards of instrumentation required at almost all the research frontiers, the emphasis on "societal implications" is vital for any research project to be funded. It serves as justification to funding institutions and the public and is frequently taken as a measure of quality and importance. Because for any scientific research "societal implications" can only be in the future, the talk of "societal implications" of present research is necessarily of prognostic or visionary character, a promise that nobody can guarantee. Natural scientists, who by their science education have no particular expertise in societal matters, are faced with the tricky rhetorical challenge to make promises that are taken as justification and quality measure of their research, without running the risk of disappointing or being accused of fraud. As a rule, they reduce the notion of "societal implication" to possible technological application of their research.

Before dealing with experimental scientists and engineers in detail, it is necessary to introduce a separate group that has provided a visionary framework and a challenge to experimental scientists. Indeed, software engineers have taken a lead in developing visions of "societal implications" of nanotechnology. Since Eric Drexler published his vision of nanotechnology in 1986, nanotechnology was framed with, if not formulated in terms of, grand engineering visions of radically changing the society by "revolutionizing" almost all the existing technologies. The visionary climate was particularly fueled by computer scientists and software engineers, like Ralph Merkle, Ray Kurzweil, Hans Moravec, and Marvin Minsky,[2] who attached to nanotechnology further transhumanist ideas and a framework of computational visions to be materialized by natural scientists and electrical and mechanical engineers. This has led to the strange situation that the current market of popular books on nanotechnology is dominated by such visionary narratives frequently authored by software engineers.[3] Writing for a general lay audience, these software engineers were not under pressure by any scientific community to substantiate their visions by scientific evidence, particularly since they wrote about subject matters beyond their own profession. As we will see in the *Policy Makers and Science Managers*, however, many of the visions were taken over by science managers and policy makers when they decided to fund nanotechnology on a large scale.

Experimental scientists and engineers are ambivalent about the visionary climate that has thus evolved. On the one hand, they feel uncomfortable with the far-reaching promises, which are not based on scientific evidence, and the resulting far-reaching expectations, which they are almost sure they cannot meet. On the other, it provides a welcome background for pointing to the required societal implication of their individual research and for promoting their specific ideas of what nanotechnology is.

Although most chemists were ignorant about nanotechnology still in the 1990s,[4] chemistry has quickly emerged as the dominating nano-science in the US by 2003 (Schummer 2004a). Despite the diversity of chemical ideas of nanotechnology (including, among others, research on nanoparticles, fullerenes, proteins, polymers, supramolecular systems, and molecular electronics), they are strictly opposed to and openly distance themselves from the ideas of nanotechnology by Drexler and his followers.[5] Nonetheless, chemists, each for their own particular research project, employ direct or indirect references to Drexler's visionary framework, though in a more modest and careful form.

For instance, George M. Whitesides (2001), a chemist who works on biomimetic chemical systems, rejects Drexler's approach while relating Drexler's broader vision to his own approach:

> Fabrication based on the assembler [*i.e.* Drexler's approach, J.S.] is not, in my opinion, a workable strategy and thus not a concern. For the foreseeable future, we have nothing to fear from gray goo. If robust self-replicating micro (or perhaps nano) structures were ultimately to emerge, they would probably be chemical systems as complex as primitive bacteria. Any such system would be both an incredible accomplishment and a cause for careful assessment.

Two pioneers in molecular electronics, Mark A. Reed and James M. Tour (2000), pose the question:

> Will it be possible someday to create artificial 'brains' that have intellectual capabilities comparable—or even superior—to those of human beings?

which they answer in a review of their *own* research as follows:

> …scientists have achieved revolutionary advances that may very well radically change the future of computing. And although the road from here to intelligent machines is still rather long and might turn out to have unbridgeable gaps, the fact that there is a potential path at all is something of a triumph. The recent advances were in molecular-scale electronics…By pushing Moore's Law past the limits of the tremendously powerful technology we already have, these researchers will take electronics into vast, uncharted terrain. If we can get to that region, we will almost certainly find some wondrous things—maybe even the circuitry that will give rise to our intellectual successor.

Richard Smalley, in the introductory part of a public speech about his very specific work on the use of carbon nanotubes for energy storage, claims:

> The list of things you could do with such a technology [nanotechnology] reads like much of the Christmas Wish List of our civilization (Smalley 1995).

The big visions circulating around the vague ideas of nanotechnology allow presenting to the public every highly specialized research project as being part, if not the central part, of one big "revolution". Due to the division of labor between scientists and the public relation departments of their institutions, the message can be disseminated without running the risk of undermining professional credibility. Universities in the US appear to be in a competition of who is leading the "revolution", as the following three headline examples from different media illustrate:[6]

> "Harvard looking to lead nanotechnology revolution."[7]

> "Houston is playing leadership role in nanotechnology revolution"[8]

> "The Physical Sciences in the UCLA College are taking a leading role in the new revolution at the nanoscale"[9]

Of course, the term "revolution" here does not refer to a conceptual or theoretical revolution in the meaning of Thomas Kuhn. Instead, it means "industrial revolution", which seems to be the biggest societal implication that today's nanoscientists can think of. Since, for scientists, "societal implications" almost exclusively means technological applications, relating their research to "industrial revolution" is the ultimate research justification and the ultimate measure of quality.

Finally, there is a small, though growing, group of natural scientist for which "societal implications" of nanotechnology has, through their professional perspective, a different meaning. Environmental scientists and toxicologists are beginning to investigate the potential harm of nanoparticles to the health of human and other living beings and their impact on ecological systems.

In sum, among the group of scientists and engineers there are three different groups with different kinds of meanings of "societal implications". Software engineers associate it with grand visions of radical changes of society in which everything becomes possible by software control. The experimental scientists and engineers who are actually engaged in nanoscale research refer to such visions in more modest and indirect form, from technological application to industrial revolutions, to legitimize their own specific research projects and to promote their particular notions of nanotechnology. For toxicologists and environmental scientists it rather means risks to health and environment, the topics of their own research.

Policy Makers and Science Managers

Once they decide to support nanotechnology research on a large scale, policy makers and science managers are in need to justify the funding to voters and other people they have to respond to. One way to do so is by making visionary promises about the revolutionary power of nanotechnology, how it will change the whole of society to the better. However, opening the visionary power box, in order to convince the skeptics, may also frighten others who are afraid of too much technological power or who oppose the suggested changes. Thus, the political talk of "societal implications" needs to be well balanced.

In the US, President Clinton was the first to make nanotechnology a political matter of high priority in 2000, so that the first political statement to the broader public was the White House press release (White House 2000) that announced the National Nanotechnological Initiative (NNI).[10] It was entitled "Leading to the Next Industrial Revolution," which the NNI later modified to its motto "Supporting the Next Industrial Revolution." Here we learn that nanotechnology is "likely to change the way almost everything—from vaccines to computers to automobile tires to objects not yet imagined—is designed and made."[11] NNI's foundational report, issued six months later, had an even bigger vision (NSTC 2000):

> The effect of nanotechnology on the health, wealth, and lives of people could be at least as significant as the combined influences of microelectronics, medical imaging, computer-aided engineering, and man-made polymers developed in this century.

The original press release also included the first public mentioning of societal and ethical implications of nanotechnology, which still puzzles interpreters today:

> Ethical, Legal, Societal Implications and Workforce Education and Training efforts will be undertaken to promote a new generation of skilled workers in the multidisciplinary perspectives necessary for rapid progress in nanotechnology. The impact nanotechnology has on society from legal, ethical, social, economic, and workforce preparation perspectives will be studied. The research will help us identify potential problems and teach us how to intervene efficiently in the future on measures that may need to be taken.

The text suggests that "societal and ethical implications efforts" is, like "Workforce Education and Training efforts", something that can be "undertaken" to "promote a new generation of skilled workers" because it can "identify potential problems and teach us how to intervene efficiently"; that it also includes the economic perspective; and that it *must* contribute to "rapid progress in nanotechnology". "Societal and ethical implications" efforts are somehow associated with education and economics and put under the imperative of progress.

Nearly four years later, when President Bush signed the 21st Century Nanotechnology Research and Development Act in December 2003, the corresponding White House press release has lost much of the grand vision tone and sounds rather like a list of various specific research projects (White House 2003):

> Nanotechnology offers the promise of breakthroughs that will revolutionize the way we detect and treat disease, monitor and protect the environment, produce and store energy, and build complex structures as small as an electronic circuit or as large as an airplane. Nanotechnology is expected to have a broad and fundamental impact on many sectors of the economy, leading to new products, new businesses, new jobs, and even new industries.

The visionary power box has largely been reduced to economic promises.[12] It would seem that politicians have returned to a balanced and pragmatist point of view that avoids stirring up fears among the American people. Interestingly, there is no more mentioning of "societal and ethical implications", although that has become a central part of the Bill,[13] so that it is worth analyzing its meaning there in some detail.

The Bill, as a novelty in the US history, requires the establishment of an American Nanotechnology Preparedness Center (Sec. 9), which shall

> (1) conduct, coordinate, collect, and disseminate studies on the societal, ethical, environmental, educational, legal, and workforce implications of nanotechnology; and
>
> (2) identify anticipated issues related to the responsible research, development, and application of nanotechnology, as well as provide recommendations for preventing or addressing such issues.

In this unsystematic collection of "implications" it remains quite obscure what "societal implications" means. Some clarification is provided when the legislators require from the general National Nanotechnology Program (Sec. 2) to consider:

> ethical, legal, environmental, *and other* appropriate societal *concerns*, including the potential use of nanotechnology in enhancing human intelligence and in developing artificial intelligence which exceeds human capacity

which should be addressed, among others, by the

> convening of regular and ongoing public discussions, through mechanisms such as citizens' panels, consensus conferences, and educational events, as appropriate (Section 2; [my emphasis]).

The list of anticipated "societal concerns" is further detailed in the requirement from the National Research Council (Sec. 5) to perform within three years a "study on the responsible development of nanotechnology" including, but not limited to:

> (1) self-replicating nanoscale machines or devices;
>
> (2) the release of such machines in natural environments;
>
> (3) encryption;
>
> (4) the development of defensive technologies;
>
> (5) the use of nanotechnology in the enhancement of human intelligence; and
>
> (6) the use of nanotechnology in developing artificial intelligence.

It seems that, for US policy makers, "societal concerns" is the generic term and means critical concerns by members or groups of the society, which can be ethical, legal, environmental, or other "appropriate" concerns, and which should be addressed and prevented by participatory models and education to make the American society "prepared" for nanotechnology. The broader concept, "societal implications", thus includes, on the one hand, the impact of ideas about future nanotechnology on such concerns, but excludes the impact of ideas in society on the development of nanotechnology.

Since the two issues that are explicitly mentioned twice—the "use of nanotechnology in the enhancement of human intelligence" and "in developing artificial intelligence which exceeds human capacity"—are explicit transhumanist visions, which are otherwise not considered nanotechnology, it is obvious that some US policy makers want to prepare their society for more than nanotechnology. Thus, unlike a shift to a more balanced and pragmatist view, as the White House press release suggests, the prospected "societal and ethical implications" of nanotechnology now include even more fantastic visions as well as possible resistance by the American people that need to be addressed by educational measures.

There are yet two other political aspects that deserve closer attention. Regardless of what it really means, nanotechnology has become a symbolic subject of international competition, much like the Cold War space program. From the first initiative to numerous speeches and the Nanotechnology Bill, "ensuring United States global leadership" (Sec. 2) is a dominant motive. Thus, every NNI/NSF report takes great pains to compare the US dollar input in nanotechnology with those in Europe and Japan, thereby overlooking low salary countries like China and South Korea who are actually quite strong in research output (Schummer 2004a). Once involved in the symbolic competition, no country wants to lag behind. Since the vague definition of nanotechnology allows to call most of current research in chemistry, physics, biomedical engineering, materials science, electrical engineering, and so on nanotechnology, relabeling of research budgets, sometimes along with effective budget cuts, is a common strategy to increase the official funding of nanotechnology by orders of magnitude.[14]

In addition to the symbolic competition by means of figure cosmetics, the focus on nanotechnology provides the opportunity to rearrange the landscape and policies of research funding. In the US, where the physical sciences and the biomedical sciences have separately been funded by the NSF and the NIH (National Institute of Health), respectively, the NNI with its Director Mihail Roco from the NSF is the strongest effort to undermine that division. Whether, in the long run, the NNI will turn into a third independent pillar or a reinforcement, and reorientation, of the NSF, any current efforts at making nanotechnology big, from getting as many disciplines involved to making nanotechnology the center of transhumanist visions (Roco & Bainbridge 2003), will have an impact on the redistribution of responsibility and power among US agencies.

In sum, for US policy makers and science managers, "societal implications" of nanotechnology has two kinds of meaning. On the on hand, it includes visions about the welcome impact on business and technology development of national concern as well as transhumanists visions of human enhancement and perfection; on the other, it includes fears of the unwelcome impacts on society, including the resistance against nanotechnological and transhumanists visions by members or groups of society. Depending on person, time, circumstances, and audience, the relative weight of the two kinds of meanings, including their various aspects, can greatly vary. In addition, policy makers and science managers also hope for an impact on symbolic leadership and the structure of governmental agencies, which both require nanotechnology being as big as possible.

Business

After the dot-com boom in the late 1990s and the bubble burst of 2000, investors are keen to find new opportunities for making much money in short time. Two business groups have quickly responded. On the one hand, nanotechnology start-ups have allied to nano-business associations in various countries to represent their common interest and propagate a blooming future of nanotechnology to its current and future sponsors, i.e. governmental and private investors.[15] On the other hand, numerous business consultants, venture capital and investment firms are seeking a share in mediating between the manufacturing business and private investors. Until recently, their efforts to attract private investors consisted largely in providing information via NanoBusiness Internet Portals and nanobusiness reports.[16] The information usually comes as a news mixture of scientific "breakthroughs", market events, political events, and "analyses" about hot investor opportunities. For instance, Forbes/Wolfe, who started issuing the first newsletter with "insider information", *Nanotech Report*, knows that **"**Stunning breakthroughs in Nanotechnology are about to transform the future of our economy and make EARLY INVESTORS RICH.**"**[17]

Nanobusiness headlines follow a simple stereotype that captures the essence of the information to be hammered into the minds of potential investors. All they need to know is that nanotechnology is about small things, but will become big business. Here are some headline quotes:

> "Small Stuff, Big Business"; "The Very Small is Getting Big"; "Nanotech Promises Big Changes by Getting Small"; "Small Is Big"; "Small Is the New Big"; "Small Science Has Big Opportunities"; "Small world's big achievement"; "Thinking Small, Winning Big"; "Big News in Small Tech"; "The Next Big Small Thing"; "From Small Dimensions to Big Business"; "Nano Research Could Mean Big Business"; "If It's Nano, It's BIG"; "Thinking Big about Nano"; "The Next Big Thing is Very, Very Tiny"

Recent efforts have tried to bring nanotechnology to a broader investor market. Since March 2004, First Trust, a bank that specializes in retirement plans, offers a "nanotechnology" mutual fund called FTNATX that largely consists of stocks from well-known companies that produce such diverse goods as chemicals, pharmaceuticals, gasoline, electricity, computers, chips, and scientific instruments.[18] Three weeks later, Merrill Lynch introduced a Nanotech Stock Index at the New York Stock Exchange,[19] which includes smaller companies of a variety of fields, such that Merrill Lynch has been charged to misuse the nano label as a tactic for fraudulent stock promotion (Reisch 2004). In their accompanying "research report" called "Nanotechnology: Introducing the Merrill Lynch Nanotech Index" (April 8, 2004), the investment bank argues (p. 2):[20] "We believe nanotechnology could be the next growth innovation, similar in importance to information technology over the past 50 years...The National Science Foundation (NSF) sees a potential market totaling $1 trillion in the next 10-12 years." What is puzzling here is not so much their professional optimism for their own stock index, but that one of the biggest investment banks worldwide refers to the NSF, which specializes in funding the physical sciences and engineering, as an authority in business matters.[21]

Indeed, NSF's forecasted $1 trillion market is quoted in almost any nanobusiness report—sometimes the "$1 trillion market" appears only as "expert estimates". The reason for NSF's authority becomes obvious when Lux Capital, a venture capital firm that focuses on nanobusiness, praises their own expertise along with their 250-page *The Nanotech Report 2003*, because they would have been "the first to recommend following government funding."[22] It does not matter if NSF's forecast is right or wrong, as long as the number meets business hopes. If governmental science funding agencies believe in nanobusiness, business advisors follow their lead, copy their visions, and sell them—in the form of quite expensive "reports"—to investors eagerly awaiting the next boom, thus creating a self-fulfilling prophecy bubble.

Transhumanists

Transhumanism is a quasi-religious movement that originated in California in the 1980s with adherents in many different countries nowadays. Transhumanists believe in futuristic technological change of human nature for the achievement of certain goals, such as freedom from suffering and from bodily and material constraints, immortality, and "super-intelligence."[23] It is quasi-religious in its members' earning for Salvation,[24] and it is futuristic in the adoption of various technological visions, such as visions of nanotechnology; the stepwise transformation of human bodies into robots; the "atom-by-atom copying of the brain"; the electronic "uploading, copying and augmentation of minds" to be connected in cyber-societies; cryonics; and space colonization to cope with over-population. Since transhumanists believe that classical humanism would rest on a static notion of human nature, they call themselves "transhumanist" to point out their teleological attitude towards radical change. Their ultimate goal is to overcome the present human condition and become "posthuman"; and many are awaiting the "singularity", a short phase of accelerated technology development that shall make all this happen.

Transhumanists have particularly great expectations for nanotechnology as envisioned by Eric Drexler. Indeed, it is the key technology vision on which most of transhumanism rests nowadays. First, they foresee the development of Drexler's "assemblers" (Drexler 1986) that should manufacture abundant materials and products of any kind to be made available for everybody, so that material needs will disappear. Second, they expect “assemblers” to become programmable tool-making machines that build robots at the nanoscale for various other transhumanist aspirations—a vision that has essentially fuelled the idea of “singularity”. Thus, they thirdly hope for nano-robots that can be injected into the human body to cure diseases and to stop (or reverse) aging, thereby achieving disease-free longevity or even immortality. Forth on their nanotechnology wish list are nano-robots that can step by step redesign the human body according to their ideas of “posthuman” perfection. Other nano-robots shall, fifth, make “atom-by-atom copies of the brain”, sixth, implement brain-computer-interfaces for “mind uploading”, seventh, build ultra-small and ultra-fast computers for “mind-perfection” and “superintelligence”, and, eighth, revive today’s cryonics patients to let them participate in the bright future.

Besides an individualist branch, which comes with a particular libertarian attitude under the label of “Extropianism” and which is organized in the Extropy Institute (www.extropy.org), there is a strong moralist approach that derives from classical utilitarianism. Assuming that all people share their goals and that the technological visions are feasible, transhumanists consistently argue that all technological efforts ought to be made to achieve their goals and that any omission to do so and any attempt to prevent this are morally wrong. However, they also acknowledge possible dangers of the envisioned technologies and argue for a rational debate in which objective risks need to be compared with the benefits.

Transhumanists have an *existential* interest in nanotechnology, as a means for the ends of personal and/or societal Salvation, and thus differ from other people who do not share transhumanist goals and for whom technologies are but means for ordinary goals. It is this difference in interest that makes transhumanists a special interest group about “societal and ethical implication of nanotechnology”. On the one hand, they have very specific ideas about what the personal and social implications will be, i.e. that nanotechnology will enable the “posthuman” condition. Thus, transhumanists are pushing the discussion on “societal and ethical implication of nanotechnology”, like William S. Bainbridge, director of various programs at the US National Science Foundation since 1992 (Roco & Bainbridge 2001, 2003), and Mike Treder, Director of the Center for Responsible Nanotechnology founded in 2002 (www.crnano.org). On the other hand, their existential end let them consider the means, i.e. the development of nanotechnology à la Drexler, much more likely and much more important than other people, which has direct implications on risk/benefit assessments.

Transhumanists generally argue for replacing subjective risks perception of a technophobic society by objective risks assessment. At the same time, however, they keep their own subjective assessment of the potential benefits, i.e. individual and/or societal Salvation, as the objective standard. Thus, in any risk/benefit analysis of nanotechnology, transhumanists are much more ready to assume risks because they personally see much greater benefits, and they see these benefits much more likely, even certain, to come. Moreover, if salvation through nanotechnology is taken as the largest possible benefit that is certain to arrive soon, the benefit of nanotechnology always outweighs whatsoever likely risk. At this point, any risk/benefit analysis becomes obsolete because the outcome is always predetermined.

Against this background, some transhumanists, including leading figures, express quite disturbing but consequent views. Max More, philosopher and Chairman of the Extropy Institute, argues for replacing the precautionary principle in legislation with what he calls the "proactionary principle" (More 2004): "People's freedom to innovate technologically is valuable to humanity. The burden of proof therefore belongs to those who propose restrictive measures." Hence, if, for instance, certain nanoparticles are only likely to cause cancer on workers of a nanotechnology firm, because some workers have actually cancer and the nanoparticles are carcinogenic on test animals, More's principle would prohibit any restriction on the nanoparticle development as long as it is not proved that these nanoparticles actually cause cancer on humans, which would require cancer experiments with humans.

Nick Bostrom, philosopher and Chairman of the World Transhumanist Association, has even more frightening views. In his discussion of the risks of technologies, he distinguishes between "endurable risks", such as nuclear reactor meltdowns and carcinogenic pollutants, and "existential risks", i.e. "events that would cause the extinction of intelligent life" (Bostrom 2003, question 3.3). While "endurable" risks are "recoverable", because "they do not destroy the long-term prospects of humanity as a whole", existential risks are not, so that transhumanist "recognize a moral duty to promote efforts to reduce existential risks". In that mixture of radical utilitarianism and apocalyptic admonition, risks are perceived only for humanity as a whole, are either recoverable for humanity or existential for humanity, and only the existential ones really count. The risks of individuals, to their health and lives, are less important because their risks can be outweighed by steps towards transhumanist salvation of humanity. It is not so much the imaginations of the "posthuman" condition, which are mostly taken from science fiction stories, but the relative disregard for individual human dignity in risk assessments, i.e. the willingness to sacrifice individuals for the sake of global salvation, that makes transhumanism so inhumane.

Following Drexler's *Engines of Creation* (1986), transhumanists combine utopian visions with distopian visions of nanotechnology to derive normative claims. Such as nanotechnology offers salvation, such does it include the potential of "existential risks". Theologically speaking, nanotechnology bears both the highest good (*summum bonum*) and the highest evil (*summum malum*), making it the most important thing one can imagine. Because nanotechnology is so powerful, "rogue states" or terrorists could abuse the power to destroy all intelligent life on earth. Since for transhumanists the technological development as such is unavoidable (technological determinism), responsible people must have command over the most advanced nanotechnology to protect humanity against evil use. Hence, advancing nanotechnology is not only required for Salvation, but also a moral obligation to avoid Armageddon. Personal motives thus perfectly harmonize with moral duties, which might be one of the reasons why transhumanism is so appealing for many.

In sum, for transhumanists the "societal and ethical implications" of nanotechnology are personal and/or societal Salvation as well as the threat of Armageddon, from both of which they derive normative claims to advance research and development of nanotechnology as fast as possible.

The Media and the Public

The most important mediators between science and society are the media. Since investigative science journalism in newspapers and magazines has rapidly decreased, the journalist's task largely consists in selecting news from a growing supply by news service companies that mostly originate from press releases. However, whether they do their own investigations or select and modify news provided by news services companies, journalists try to apply the perspectives and interest foci on science which they think their readers have. Thus, within the scope of available news, the media coverage of topics corresponds to a large degree to the interests and concerns of the public, to what the public understands by "societal implications" of nanotechnology.

To get a rough quantitative idea of how the media reports on nanotechnology, I have analyzed all the 160 news articles published between December 5, 2003 and June 30, 2004 that are archived by the news portal Topix.net under the category "nanotechnology" (www.topix.net/tech/nanotech). Topix.net covers mainly US media that are available online, including local and national newspapers and general magazine as well as many topical magazines and online media. Although the coverage is not really representative of all media, because only those available online and free are included, it is sufficiently diverse to provide a semi-quantitative picture.

Of all these articles on nanotechnology, 32.4% appeared in general newspapers and magazines, 30.0% in business magazines, 18.8% in science & technology magazines, and another 18.8% in *smalltimes*, a magazine that combines nano-business with nanotechnology news. Although the distinction between business and science & technology magazines is still discernible in their mission statements, particularly in older ones, the boundary is increasingly blurred, so that *smalltimes*' publishing concept of combining both might be forward-looking. The convergence of business magazines and science & technology magazines suggests that people interested in business are also increasingly interested in science & technology and vice versa. If we divide up the coverage of *smalltimes*, we may say that about 40% of all nanotechnology media coverage appears in business magazines.

What do these various media report on nanotechnology? Table 1 presents the results of the article content analysis of various topics of the nanotechnology media coverage, both for all media types together and for the class of general newspapers and magazines. The dominating topic is business, which consists of market news on new companies, changes or new cooperations or alliances of former companies, investment opportunities, and general market trends in the local, national, or global nanotechnology business. Politics includes the opinions and decisions on nanotechnology by policy makers, which, as a rule, are about funding nanotechnology, from county council decisions to "Bush's Signs $3.7 Billion Nanotechnology Bill". Most reports on science are not about research but about grants for new research projects or new nanocenters, with headlines, like "University XY gets $3 Million Nanotech Grant". If we add up these three categories, it turns out that 71.9% of all articles about nanotechnology are about money and only about money. In the general media, as much as 77.0% are about money, because nanotechnology is mostly covered in the business section of newspapers. Actual research is covered only in 11.9% of all articles, although 18.8% of all articles appear in science & technology magazines. In the general media, reports on actual research (5.8%) or education (1.9%) are almost negligible. Surprisingly, also nanotech visions play a minor role and are mainly published in science & technology magazines including *smalltimes*.

Table 1.
Topics of nanotechnology media coverage

	All Media (%)	General Media (%)
Business	50,6	55,8
Politics	7,5	7,7
SciTech/Grants	13,8	13,5
SciTech/Research	11,9	5,8
SciTech/Education	3,1	1,9
SciTech/Visions	5,6	1,9
Concerns (ELS)	5,0	9,6
Others	2,5	3,8

The category of Ethical, Legal, and Societal Concerns (ELS) has been filled only on the occasion of three specific events during the period of investigation: a US study on the potential toxicity of buckyballs on fishes; a British study on the possible transfer of nanoparticles from a pregnant rat to the fetus; and a Swiss report by the insurance company Swiss Re on how to insure nanotech firms. These concerns are mostly covered by general media and are, apart from money, the only topic worth mentioning here (9.6%). Since the American media responded to almost all such studies during the period, including foreign studies that are usually not much considered, it is likely that more such studies can considerably increase the media coverage of Ethical, Legal, and Societal Concerns.

Assuming that the media coverage roughly corresponds to the average American public interests in nanotechnology, we may conclude that currently 3/4 of the interests are about money and 1/10 about health and safety concerns, which might rise on special occasions. That is what, in this order, matters to people, what the average American public is supposed to understand by "societal and ethical implications" of nanotechnology.[25]

Cultural and Social Scientists

Cultural and social scientists, including philosophers, have a much more sophisticated meaning of "societal and ethical implications" of nanotechnology than any of the groups discussed before, which is therefore impossible to review in the few following remarks, the more as this group comprises many different disciplines.[26] As researchers they are first of all interested in analyzing and understanding the *mutual* impact between nanotechnology and society. Rather than taking technology as a given mysteriously autonomous force with one-way impacts on society, they consider scientists and engineers who actively work in nanotechnological research and development as members of society. On the one hand, they are interested in how cognitive and instrumental traditions, cultural values and belief systems, and societal needs and interests groups contribute to the generation and shape of nanotechnology. (Thus, this paper tries to identify interests groups and their different meanings of "societal and ethical implication".) On the other, they investigate how *ideas* about nanotechnology, from research papers to political statements and journalist reports to visionary promises, move into society and could impact on or are in conflict with ethical theories, cultural values, belief systems, and societal needs. And since they consider science and technology as part of society, they are also interested in how the emergence and developments of nanotechnology change the disciplinary landscape and the general relationship between science and engineering.

The interest of cultural and social scientists in "societal and ethical implications" of technology is first of all a professional interest in understanding, and in this regard it is fair to say that they are, among all groups mentioned in this paper, the definite experts in these matters. Their specific interest in nanotechnology may differ, however. Because there are many different theories around on the mutual impact between technology and society, nanotechnology might serve as a particular case study for supporting one of the various theories, or for by promoting one or the other notion of post-xy, from post-modernism to post-normal science. In addition, the nano-hype, with its abundant talk of "societal and ethical implications" and the increasing budgets for related efforts, provides new opportunities for cultural and social scientists, from orientating research towards more current issues and engaging in partnership models with scientists and engineers to securing research funds or career opportunities.

Apart from research, politicians increasingly expect from cultural and social scientists to "educate" the public beyond their professional duties of academic education. Thus, the already quoted White House press release announced to "undertake" "ethical, legal, societal implications…efforts…to promote a new generation of skilled workers". And the US Nanotechnology Act requires "mechanisms such as citizens' panels, consensus conferences, and educational events" to shape the public opinion. Whether or not cultural and social scientists as individuals are willing to engage in such promotional events, it is questionable if they are the real experts here, rather than politicians, talk show masters, or media monopolists. I suspect that a techno-scientistic misconception of the cultural and social sciences underlies all those political expectation: such as natural scientists can continuously be moved from 'pure' research to applied research and engineering, such can cultural and social scientists be moved from cultural and sociological research towards cultural and social engineering. While scientists and engineers have actually control over their experimental systems and can manipulate them for either the study of behavior or the optimization of performance, cultural and social scientists never have any such control over social systems, not even in sociological experiments. Thus, the political expectations seem to rest on wrong advices about the methodology of the cultural and social sciences.

How can they cope with such ill-advised political expectations? One option would plainly be to deny the expected expertise, at the risk of loosing funding for important *research* in "societal and ethical implications". Another option would be to assume the expertise, based on the authority of knowledge and academic independence. However, once they engage in the promotion of political goals, whether they personally subscribe to these goals or not, cultural and social scientists lose just the academic independence on which their expertise is supposed to rest. The only viable option seems to be assuming the role of neutral mediators between different interest and opinion groups. Here, the expertise rests not so much on talk show master qualities than on the professional capacities to analyze different positions and their underlying assumption, to identify misunderstandings, common grounds and insurmountable differences, to define conditions of fair disputes, and to know something about the dynamics of social conflicts and cultural history.

In sum, for cultural and social scientists "societal and ethical implications" of nanotechnology means the mutual impact between nanotechnology and society from many different perspectives. Their main interest is a research interest in understanding the particular situation or in defending a general theory. While such research might bring up models for better mediating between society and nanotechnology, it is neither their expertise nor their primary interest to meet political expectations of shaping the public opinion.

The Mutual Impact of Meanings: Semantic Dynamics

In the previous section we have identified the meanings of "societal and ethical implications" of nanotechnology by various groups and their particular interests. These groups relate to major societal subsystems (literature, natural science and engineering, politics, business, religion, media, cultural and social science) by being those parts of the subsystems that are actively engaged in the current debate on "societal and ethical implications" of nanotechnology in the US. Having used the analytical classification of societal subsystems as a heuristic tool for identifying the groups and their meanings, we can now go one step further and analyze the mutual semantic impact between these groups to study the dynamics of the debate. Unlike analytical subsystems, the groups and their members overlap and exchange meaning. Somebody can, for instance, be a transhumanist and an engineer at the same time, or move from science to business, or transfer meaning from business to politics. There may even be alliances between two or more groups or a broader movement in which one group takes a lead.

In this section, rather than providing a complete analysis of the semantic dynamics of the debate, I perform only a preliminary study to identify the dominating groups and their meaning(s) of "societal and ethical implications" of nanotechnology. Based on the material from Section 2, I collect evidence about the mutual impact of the groups' meanings and try to distinguish between influential and less influential groups and between original and mediated meanings. It is understood that "impact" here does not mean political impact but exclusively semantic impact, i.e. the impact of group A's meaning of "societal and ethical implications" on group B's meaning.

The impact of science fiction authors is perhaps most difficult to estimate. The rapid growth of the nano-science fiction book market suggest that their meaning has a growing impact on the public, although that is not yet discernable in the brief media analysis of Section 2.6, so that the impact might still be limited to specific groups, like the community of science fiction readers. We have evidence, however, for a strong impact on both transhumanists and visionary engineers, since most of their visions appeared in science fiction stories before, as well as for some impact on scientists, including the posthumous founding figure Richard Feynman. All these impacts are indirect, however, because the actual meaning of "societal and ethical implication" changes when ideas are transferred from fiction to forecasting or to normative systems. As professional fiction authors, the originality of their nanotechnology vision has been very high, although they recently began to borrow from visionary software engineers.

Thus, visionary software engineers have an increasing impact on recent science fiction authors, as well as strong impacts on transhumanists, business people, and to some extent on politicians, because they feed theses groups with visions and are frequently engaged themselves in business or transhumanism. By providing a rhetorical framework to nanoscientists for publicly justifying actual research, they also influence the meaning of this group. Their meaning of "societal and ethical implication" of nanotechnology is semantically original because, even if they borrow ideas from science fiction authors, they transform them into forecasts by claiming that these will be the actual "societal and ethical implications".

Nanoscientists are less influential because of their underdeveloped notion of "societal and ethical implications", which is taken over from other groups in a moderated form and thus not very original. However, to some degree they have a discernable impact on the media/public, as reflected in media coverage, and on politicians, as the recent political turn towards more specific research projects as opposed to Drexler-like ideas of nanotechnology illustrates.

Toxicologists and environmental scientists seem to have a strong impact on the media/public, although they are hardly involved in the current debate yet. Representing the science-based side of concerns, their meanings are not only original but also to some degree taken over by politicians, as the Nanotechnology Bill suggests, and by cultural and social scientists.

Politicians have a discernable impact on the media/public and, through funding agencies, a strong impact on nanoscientists. As we have seen, they also impact the investment business that follows governmental funding. Contrary to their strong impact is the low degree of originality of their meaning of "societal and ethical implications" that, apart from national connotations such as symbolic leadership and military application, combines various other meanings, though with particular accentuation. The combination of strong semantic impact and strong but selective semantic susceptibility, along with low semantic originality, makes them the most important and powerful mediators in the debate.

Business is very influential on the media, as the coverage illustrates, and on politicians, who particularly emphasize the economical prospects of nanotechnology. Because both several nanoscientists and visionary engineers run their own nano-business, such that a move towards entrepreneurship seems to be an appealing option for members of both groups, it is assumed that the business meaning also impacts these groups to some degree. Although the idea that nanotechnology will be the next "big thing" on the investment market sounds less original, it is nonetheless the original semantic contribution from business to the meaning of "societal and ethical implications" of nanotechnology—provided that governmental agencies like NSF did not raise the business idea earlier.

The impact of transhumanists is again difficult to estimate. Since we find transhumanists particularly among visionary engineers, such that both groups strongly overlap, and also among science fiction authors and in governmental agencies, it is reasonable to assume that they impact the meaning of these groups accordingly. In addition, the explicit mentioning of transhumanist vision in the US Nanotechnology Act suggests that the impact on policy makers is not insignificant. Since transhumanists have taken over most, if not all, ideas about nanotechnology from visionary engineers and science fiction authors, they might seem to be less original. However, similar to the transformation from fiction to forecasting, they transform these ideas into a normative religious system, such that the meaning of "societal and ethical implications" of nanotechnology considerably changes, which is an original semantic contribution.

For the media/public in a democracy we may, despite the current lack of evidence, assume that they have a strong impact on politicians. The strong focus of current nanotechnology news on business, particularly on investment opportunities, suggests also some impact on business. Furthermore, as we have seen in Section 2.2, nanoscientists, or their institutions, increasingly address the public through press releases, and thereby adjust their meaning to media standards. The media is clearly the least original group and, not surprisingly, an important mediator with both some semantic impact and a strong semantic susceptibility.

Finally, the sophisticated meaning of "societal and ethical implications" of cultural and social scientists, though being highly original, has no discernable impact on any of the other groups up to now. The only indirect impact seems to be on transhumanists, because the leading and most eloquent transhumanists not only have a PhD in philosophy, but also developed their views against the background and in opposition to classical humanist ideas.

Tables 2 and 3 summarize the results of the mutual impacts and the originality of meanings among the groups. It is understood that the analysis is thus far only preliminary and that further research can provide more evidence of impacts and a more sophisticated fine-tuning. Within these limitations, however, we may try to analyze the role of the various groups and their meanings in the debate on "societal and ethical implications" of nanotechnology.

Due to their low overall impact, both nano-scientists and cultural and social scientists play only a marginal role in the debate, despite the fact that the originality degrees of their meanings greatly differ. Two other groups, politicians and the media, are largely mediators of meaning, because of their low originality degrees along with both considerable impacts and susceptibilities. That does not mean that politicians and the media play no important role in the debate, however, since they can highlight one meaning at the expense of others. Among the remaining five groups with medium to high impacts and original meanings, toxicological and environmental scientists stand out because they have thus far no discernable direct impact on either of the four other groups, such that their impact is limited to mediation through the media or politicians. Hence, the semantic core of the debate on "societal and ethical implications" of nanotechnology consists of the meanings of four groups, which I call the *semantic leaders*: science fiction authors, visionary engineers, transhumanists, and business people.

Table 2.
The mutual impact of the meanings of "societal and ethical implications of nanotechnology" among interest groups.

	SciFi-Authors	Vis. Engineers	Nano-Scientists	Tox. & Env. Sci	Poli-ticians	Busi-ness	Trans-humanists	Media / Public	Cult. & Soc. Sci.
SciFi-Authors		++					++	+	
Vis. Engineers	++		+		+	++	++		
NanoScientists					+			+	
Tox. & Env. Sci.					+			++	+
Politicians			++			++		+	
Business		+	+		++			++	
Transhumanists	+	++			++				
Media / Public			+		++	+			
Cult. & Soc. Sci.							+		

Table 3.
Characterization of the meanings of "societal and ethical implications of nanotechnology" by interest groups.

	Impact	Susceptibility	Originality
SciFi-Authors	medium	low	high
Vis. Engineers	high	medium	high
NanoScientists	low	medium	low
Tox. & Env. Sci.	medium	low	high
Politicians	medium	high	low
Business	high	medium	high
Transhumanists	medium	medium	high
Media / Public	medium	high	low
Cult. & Soc. Sci.	low	low	high

The semantic leaders of the debate form a strongly connected cluster with regard to the mutual impact of their meanings of "societal and ethical implications" of nanotechnology (Figure 1). That is no coincidence because their meanings, unlike those of all the other groups, refer to highly visionary ideas. Indeed, the same visions can easily be, and have actually been, exchanged between science fictions authors, visionary engineers, and transhumanists. What science fiction authors invent in an experimental manner as fictional "societal and ethical implications" of nanotechnology can become seriously meant forecasts by visionary engineers and a pathway towards Salvation with normative claims by transhumanists, and vice versa. Business differs from these groups by focusing only on those visionary forecasts that can be translated into business and investment opportunities. The semantic leaders thus form a visionary alliance that is rather robust against the less visionary meanings by other groups. Only business is indirectly susceptible to corrections if, for instance, major concerns from toxicological and environmental scientists are mediated via politicians and the media/public. In particular, the alliance is not very susceptible to both the more realistic views of the prospects of nanotechnology by experimental scientists and the more sophisticated meanings of "social and ethical implications of nanotechnology" by cultural and social scientists. Even if politicians were not fostering the visionary climate as they do, they would have no discernable impact on science fiction authors, visionary engineers, and transhumanists.

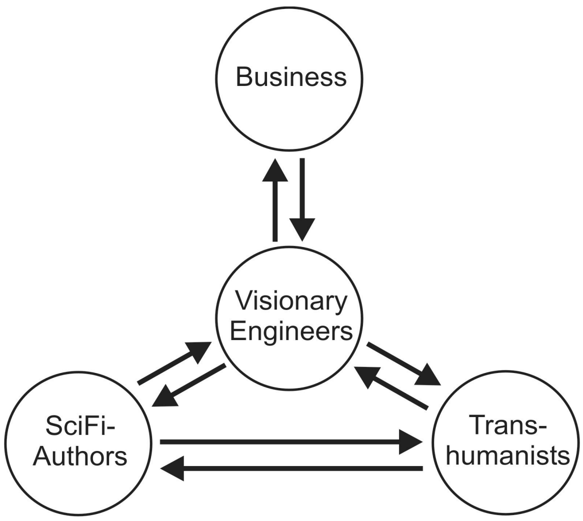

Figure 1. The visionary alliance in the debate on "societal and ethical implications of nanotechnology". Arrows indicate the impact of meaning as described in the text.

Conclusion: An Outlook into the Near Future

Provided that the analysis of the semantic dynamics of the debate on "societal and ethical implications" of nanotechnology is, despite its simplifications and preliminary state, correct enough to identify the semantic leaders and the visionary alliance, we may try to guess some possible developments. And since most about nanotechnology is about the future, I will conclude with a brief speculative outlook into the near future that is based on the analysis, some common sense psychology, and lessons from the history of science.

Due to the lack of checks and balances, the visionary alliance will certainly drive the visionary climate further through feedback loops and will disseminate their visions more into the broader public via the susceptible media. Since visions, rather than transferring information, induce hopes and fears, emotions are likely to determine the "societal and ethical implications of nanotechnology" more than anything else.

In economics, which is strongly driven by hopes and fears, the few existing internal efforts to prevent the next bubble on the investor market seem to be much too weak compared to the expectations set free by the visions. The increasing number of investment firms or gurus who explicitly warn of the next bubble do everything to make exactly this happen, because their simple message to investors is that one should invest now and get out before the bubble bursts. Hence, the dotcom phenomenon seems to be likely to repeat on the nanotech market, the more as a bubble is the most profitable period for many investors and investment mediators. If the bubble burst is not an inherent part of that development, a series of serious news about the toxicity of some nanoparticles might be able to cause the unstable system to collapse.

There are more serious events likely to come than the ups and downs of the stock market. The visionary message of unlimited power to create new things and to shape the entire world anew atom-by-atom will likely split people who are to some degree interested in science into three groups: those with strong hopes, those with strong fears, and those who feel nauseated by dubious visions. Because the hopes will, of course, be frustrated, the likely net result of the visionary messages is strong hostility towards science from all three groups. If science managers and politicians are successful in getting most of the science and engineering disciplines on the nano-bandwagon, the resulting hostility is not one from single societal groups against a single discipline, but from the majority against all of science and engineering, i.e. a broad anti-scientific movement.

The societal impacts of nanotech visions essentially differ from the impacts of software visions, because the former is about the manipulation of matter whereas the latter is only about writing commands for machines. Visions about artificial intelligence (AI), which were circulated since the 1950s, slowly died in the face of technical problems and misconceptions of human intelligence, without preventing people from, say, using computers. It seems to be no coincidence that software engineers have transferred AI visions to nanotechnology to establish a new visionary terrain. However, the new terrain is actually an old visionary terrain that has a long historical legacy of cultural fears and frustrated hopes and that is imbued with sensitive notions of which the semantic leaders seem to be rather ignorant.

Visions about unlimited wealth and immortality by manipulating the ultimate building blocks of nature have fascinated Europe from the 13th to the 18th century. Hopes made people blind and susceptible to numerous frauds; kings, like Philip IV of France and Edward III and Henry VI of England, used the swindle on a large scale to finance their wars; many researchers, after years of unsuccessful laboratory attempts, dropped their interest in experimental science altogether, considered it worthless and harmful to knowledge, and retreated into contemplation or mystics; priests and theologians, if they were not personally involved, condemned any manipulation of matter as tampering with Nature or God, as the sin of hubris (Ogrinc 1980, Obrist 1986, Schummer 2003). In the 19th century, when modern chemistry had replaced the alchemical visions and emerged as the model of the experimental laboratory sciences, chemists made new promises of experimentally analyzing the true ultimate building blocks of nature and manipulating them for the benefit of society, upon which writers started an unprecedented metaphysical and quasi-moral campaign that not only created the powerful rhetorical weapon of the 'mad scientist', but also established the ongoing split between the so-called "two cultures" (Schummer, forthcoming). In the 20th century, similar stories repeated several times. From the chemical industry, who promised a perfect world made of new materials or unlimited food from crops that are immune against pest either by pesticides or genetic modification, to nuclear engineers, who promised unlimited energy by atomic fission or fusion—each time the visionary propaganda downplayed any possible problems or risks, denounced critical voices, caused fears and hostility, and frustrated all those who were naive enough to believe in the recurring visions. Due to the visionary alliance, nanotechnology has every prospect of becoming the next big thing, even bigger though.

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[1] See http://en.wikipedia.org/wiki/Cyberpunk and http://en.wikipedia.org/wiki/Postcyberpunk (29 June 2004).

[2] Minsky, Merkle, Kurzweil, and Moravec are all directly or indirectly involved in transhumanism. Minsky serves on the Board of the Extropy institute (www.extropy.org); Merkle is director of Alcor (www.alcor.org), a transhumanist organization specialized in cryonics; Kurzweil's book *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (1999) is one of the leading visions for transhumanists; and Moravec wrote the first issue of the *Journal of Transhumanism* (Vol. 1, 1998), later called *Journal of Evolution and Technology*.

[3] For a detailed analysis of current popular books on nanotechnology and the public interest in these books, see Schummer (2005).

[4] For instance, an anthology on the "Challenges and Visions" of chemistry in the 21st century published by the American Chemical Society in 1998 did not yet include a mentioning of nanotechnology (Barkan 1998).

[5] See, for instance, the Drexler-Smalley debate in *Chemical & Engineering News* , 81, No. 48 (December 1, 2003), 37-42.

[6] Note that the term "nanotechnology revolution" goes back to a book co-authored by Drexler (Drexler, Peterson & Pergamit 1991) before it was adopted in 2000 in the motto of the National Nanotechnology Initiative "Supporting the Next Industrial Revolution".

[7] *Post Harvard: An Online Community for Hayward Alumni* (News from 19 May 2004) [https://www.aad.harvard.edu/devel/html/news_nanotechnology.html]
[8] *Houston Business Journal* (19 January 2004) [www.bizjournals.com/houston/stories/2004/01/19/focus2.html]
[9] *UCLA College Report* : " It's a Small, Small World", Vol. 2, Spring/Summer 2004 [www.cnsi.ucla.edu/small_world.pdf].
[10] For a more detailed analysis of the political development, see Fogelberg & Glimell 2003, pp.40-44, and Glimell 2004.
[11] The sentence was actually taken from a brochure issued shortly before by the National Science and Technology Council (NSTC 1999) which spelled out the vision in more detail, reminding of Eric Drexler's earlier vision.
[12] In the NSF report on *Societal Implications of Nanoscience and Nanotechno logy* from 2001 (Roco & Bainbridge 2001), "societal implications" further includes the impact on industrial manufacturing, national economy, medicine, environment, space exploration, national security, and "American leadership", as well as the needs for moving nanotechnology to the market, interdisciplinary education, and workforce preparation for future nanotechnology business.
[13] http://thomas.loc.gov/cgi-bin/query/C?c108:./temp/~c108PRZXRc
[14] To provide but one example from Germany, which has continuously been cutting down research and education budgets: A report by the federal Ministry for Research and Education (BMFT 2002a), published in January 2002, still listed the total amount of €71.8 million of federal funding for nanotechnology for the total period from 1997 to 2005; five months later, the same ministry issued a nano-report (BMFT 2002b), published in June 2002, claiming that federal funds for nanotechnology had already been €149.2 million from 1998-2001.
[15] For instance, USA NanoBusiness Alliance (www.nanobusiness.org), European NanoBusiness Association (www.nanoeurope.org), Canadian NanoBusiness Alliance (www.nanobusiness.ca), Israeli NanoBusiness Alliance (www.nanobusiness.org.il); in the US there are at least 17 other local and state alliances (see www.nano.gov/html/funding/businessops.html)
[16] For nanobusiness Internet portals, see www.nanoinvestornews.com, www.nanoapex.com, www.nanotechnologyinvestment.com, www.nanoxchange.com, and www.nanovip.com; also www.smalltimes.com has a strong focus on business (see Section 2.5). For a list of 64 nanobusiness reports, see www.researchandmarkets.com/search.asp?q=nanotechnology
[17] www.newsletters.forbes.com/nanotech/ (June 30, 2004).
[18] www.ftportfolios.com/Common/dp/portfoliosummary-print.asp?fundid=3761&Trust=nate1 (last visited, 30 June 2004). Major stocks include Dow Chemicals, Dupont, Exxon, General Electric, Hewlett-Packard, IBM, Intel, Motorola, Varian, and Veeco Instruments.
[19] www.ml.com/about/press_release/04012004-1_nanotech_index_pr.htm (June 30, 2004).
[20] www.ml.com/about/press_release/pdf/04012004_nano_index.pdf (June 30, 2004).
[21] The reference seems to be Roco & Bainbridge 2001, p. 3 (Section 2: "Nanotechnology Goals").
[22] http://www.luxcapital.com/nanotech_report_b.htm (June 30, 2004).
[23] See the information on the website of the World Transhumanist Ass ociation (www.transhumanism.org); particularly informative are "The Transhumanist Declaration" (December 2002) and "The Transhumanist FAQ: A General Introduction" written by philosopher Nick Bostrom (Bostrom 2003). The WTA has two publication media, Transhumanism (www.transhumanism.com) a board for articles and news, and the *Journal of Evolution and Technology* (www.jetpress.org). For an early and partly distanced view, see also Regis 1990.
[24] The religious character is a matter of degree and varies from individual to individual. All transhumanists subscribe to the distinction between being human (the state of striving for Salvation) and being posthuman (the state of Salvation), but they may differ in two regards. First, transhumanist may differ in whether the only existential purpose of being human is

striving for Salvation (transcendence) or whether there are other purposes of equal importance. Second, they may consider the transformation from the human state to the posthuman state, which reflects the theological distinction between immanence and transcendence, discontinuous or continuous.

[25] The average public interest greatly differs from people with a strong interest in nanotechnology, excluding researchers and experts in nanotechnology. Here, the visionary literature, including transhumanist visions and nano-investor guides, is the dominant interest focus (see Schummer 2005).

[26] For a bibliography, see Schummer 2004d.