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

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Abstract: The paper first analyzes the different meanings of and interests in "societal and ethical implications of nanotechnology" by science fiction authors, scientists and engineers, policy makers and science managers, business people, transhumanists, the media, and cultural and social scientists. Based on the mutual semantic impact among these groups, a dynamical model of the debate on "societal and ethical implications of nanotechnology" is developed and subjected to social network analysis for identifying the semantic leaders and mediators in the debate. I conclude from this analysis and from the cultural history of science that the most likely impact of nanotechnology on society in the near future is a strong anti-scientific movement.

1. Introduction

Along with the first visionary ideas of nanotechnology, ideas about its possible cultural and social impacts were articulated.[1] When the US National Nanotechnology Initiative (NNI) was launched in 2000, the program included from the very beginning funds for "societal and ethical implications of nanotechnology". It seems that engineers and policy makers have learned from the past, notably from the consumer disaster with genetically modified organism, 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.

There is nothing wrong with the model of partnership between scientists and engineers, on the one hand, and cultural and social scientists, on the other, as both groups can immensely benefit from each other, for the overall benefit of the society. This is particularly the case, if both groups learn from each other and respect their different perspectives, goals, and problem approaches. It is difficult, though, to apply the model successfully to nanotechnology at its present state, because nanotechnology appears to be too immature.

Nanotechnology's immaturity has a conceptual aspect and a social aspect that are both relevant here. Conceptually, the lack of any meaningful definition of nanotechnology has led to the current situation that in almost all the science and engineering disciplines researchers relabel their work "nano", without having anything new in common and without showing any remarkable degree of interdisciplinarity.[2] In such a situation of hype, the partnership model becomes difficult to apply. Cultural and social scientists are uncertain about which research projects should really count as "nano", such that their choices might depend rather on media presence 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 another problem.

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[1] Eric Drexler: *Engines of Creation: The Coming Era of Nanotechnology*, New York et al: Anchor Pr., Doubleday, 1986.

[2] Schummer, J.: 2004a, 'Multidisciplinarity, Interdisciplinarity, and Patterns of Research Collaboration in Nanoscience and Nanotechnology', *Scientometrics*, **59**, 425-465; Schummer, J.: 2004b, 'Interdisciplinary Issues of Nanoscale Research", in: D. Baird, A. Nordmann & J. Schummer (eds.), *Discovering the Nanoscale*, IOS Press, Amsterdam (forthcoming).

Nanotechnology is not only primarily articulated in visionary terms, these visions also appear to be visions about "societal and ethical implications" of nanotechnology. It seems that nanotechnology has induced a renaissance of the cultural and social sciences, when natural scientists, engineers, policy makers, science managers, business people, journalists, transhumanists, and science fiction authors all talk about "societal and ethical implications". How can cultural and social scientists still contribute to such a vivid debate? Would any of the strong groups, which have already strong opinions about what the "societal and ethical implications" of nanotechnology will be, listen to academic reflections? Despite nanotechnology's immaturity, it seems already too late for cultural and social scientists to become engaged in the debate.

Yet, 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, the dynamics of this debate will certainly determine the future shape of nanotechnology, including its future "societal and ethical implications". Hence, by studying the debate, cultural and social scientists can make important contributions to the understanding of both current and future "societal and ethical implications" of nanotechnology.

My first contribution (Section 2) 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. 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 meaning. 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 try to map the mutual impacts of these meanings among the interests groups of the debate, i.e. how one group influences the meaning of "societal and ethical implications" of the other (Section 4). The results are put into a raw mathematical model of the dynamics of the debate on which I perform some social network analyses to identify the semantic mediators and the semantic leaders, i.e. the groups whose meanings dominate the debate. This allows finally drawing some conclusions on what the likely "societal and ethical implications" of nanotechnology will be in the near future (Section 4).

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

2.1 Science Fiction writers

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 make 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.[3] 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

[3] Anthony S. Napier: "Nanotechnology in Science Fiction" [http://www.geocities.com/asnapier/nano/n-sf/books.html] last visited, 28 June 2004.

founding myth of nanotechnology.[4] Invisibly small devices or the manipulating 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-of-matter was the pivotal theme in all 19th-century 'mad scientist' stories, which in turn go back to medieval and early modern satires of alchemy.[5] 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.[6] And unlike the visionary engineers who made nanotechnology prominent by making epistemic claims about a likely future (Section 2.2), science fiction authors explicitly declare that their works are invented narratives, such that both texts types are linguistically well distinguishable and still have quite separated readerships, despite border-crossing authors who increasingly blur the boundary.[7]

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,[8] 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. But 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.[9] 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. Instead of conveying a simple moral message, it is rather up to reader to make their own positive or negative judgments on the fictional technology's impacts on society. While many readers might feel uncomfortable, Cyberpunk has, as a matter of fact, inspired many, if not all, visions of transhumanist utopia (see Section 2.5).

Few nano-science fiction stories directly prompt moral questions about technology. An example is Michael Flynn's *Nanotech Chronicles* (1991). However, Flynn (particularly in

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[4] Milburn, C.: 2002, 'Nanotechnology in the age of post-human engineering: science fiction as science', *Configurations*, **10**, 261-295.

[5] Schummer, J.: "Historical Roots of the 'Mad Scientist': Chemists in 19th-century Literature", *Ambix* (forthcoming).

[6] Landon, B.: 1997, *Science Fiction After 1900: From the Steam Man to the Stars*, New York: Twayne. For nano-science fiction, see also Landon, B.: 2004, "Less is More: Much Less is Much More: The Insistent Allure of Nanotechnology Narrative in Science Fiction", in N.K. Hayles (ed.): *NanoCulture: The New Technoscience and its Implications for Literature, Art, and Society* (forthcoming).

[7] Schummer, J.: 2004c 'Reading Nano: The Public Interest in Nanotechnology as Reflected in Book Purchase Patterns', *Public Understanding of Science* (forthcoming).

[8] Hirsch, W.: 1957-58, 'The Image of the Scientist in Science Fiction. A Content Analysis', *American Journal of Sociology*, 63, 506-12.

[9] See http://en.wikipedia.org/wiki/Cyberpunk and http://en.wikipedia.org/wiki/Postcyberpunk

"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. The exceptional case is 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). Apart from making a living and from entertaining readers, their major interest seems to be to make readers think about general political and moral issues and about the place of technology in society, without providing simple answers or moral messages. Many have taken visionary ideas from Eric Drexler (Section 2.2) and many have in turn inspired transhumanism (Section 2.5).

2.2 Scientists

Research without "societal implication" is equivalent to the much-denounced research in the "ivory tower" for which funds have been drastically 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.

Since the engineer Eric Drexler invented nanotechnology in 1986, it was framed with, if not formulated in terms of, a grand engineering vision of radically changing the society by "revolutionizing" almost all the technologies. The visionary climate was further fueled by computer scientists and software engineers, like Ralph Merkle, Ray Kurzweil, and Marvin Minsky,[10] who attached to nanotechnology transhumanist ideas (see Section 2.5) and a framework of computational visions to be materialized by natural scientists and electrical and mechanical engineers. Written in popular books for a general audience, these software engineers were not under pressure by the 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 Section 2.3, many of the visions were taken over by science managers and policy makers when they decided to fund nanotechnology on a large scale.

For scientists the visionary climate that has thus evolved is ambivalent. 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

[10] Minsky, Merkle, and Kurzweil 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, and Kurzweil's book *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (1999) is one of the leading visions for transhumanists.

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,[11] 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.[12] 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, a chemist who works on biomimetic chemical systems, writes:[13]

> "Fabrication based on the assembler 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, pose the question:[14]

> "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 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 work on the use of carbon nanotubes for energy storage, claims:[15]

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

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

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11 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 (P. Barkan (ed.): *Chemical Research – 2000 and Beyond: Challenges and Visions*, Washington, DC: American Chemical Society, 1998).

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

13 George M. Whitesides: "The Once and Future Nanomachine: Biology outmatches futurists' most elaborate fantasies for molecular robots", *Scientific American*, September 16, 2001

14 Mark A. Reed & James M. Tour: "Computing With Molecules", *Scientific American*, June 20, 2000.

15 R. Smalley: "Nanotechnology and the Next 50 Years", paper presented at the University of Dallas - Board of Councilors, December 7, 1995 [http://smalley.rice.edu/Papers/dallas12-96.html]

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:[16]

> "Harvard looking to lead nanotechnology revolution"[17]
>
> "Houston is playing leadership role in nanotechnology revolution"[18]
>
> "The Physical Sciences in the UCLA College are taking a leading role in the new revolution at the nanoscale"[19]

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.

In sum, among the group of natural scientists and engineers there are three different kinds of meanings of "societal implications". Engineers, particularly software engineers, associate it with grand visions of radical changes of society in which everything becomes possible by software control. The natural scientists engaged in nanoscale research refer to such visions in more modest form, from technological application to industrial revolutions, to legitimize their own 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.

2.3 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 in 2000, so that the first political statement to the broader public was the White House press release that announced the National Nanotechnological Initiative (NNI).[20] 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

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[16] Note that the term "nanotechnology revolution" goes back to a book co-authored by Drexler (K. Eric Drexler, Chris Peterson, and Gayle Pergamit: *Unbounding the Future: the Nanotechnology Revolution*, New York 1991) before it was adopted in 2000 in the motto of the National Nanotechnology Initiative "Supporting the Next Industrial Revolution".

[17] *Post Harvard: An Online Community for Hayward Alumni* (News from 19 May 2004) [https://www.aad.harvard.edu/devel/html/news_nanotechnology.html]

[18] *Houston Business Journal* (19 January 2004) [http://www.bizjournals.com/houston/stories/2004/01/19/focus2.html]

[19] *UCLA College Report*: "It's a Small, Small World", Vol. 2, Spring/Summer 2004 [http://www.cnsi.ucla.edu/small_world.pdf]

[20] The White House, Office of the Press Secretary: "National Nanotechnology Initiative: Leading to the Next Industrial Revolution" (January 21, 2000) [http://clinton4.nara.gov/WH/New/html/20000121_4.html].

change the way almost everything – from vaccines to computers to automobile tires to objects not yet imagined – is designed and made".[21] NNI's foundational report, issued six months later, had even a grander vision:[22]

> 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:[23]

> 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. There is no more mentioning of "societal and ethical implications", although that has become a central part of the bill.[24] 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.

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[21] The sentence was actually taken from a brochure issued shortly before by the National Science and Technology Council "Nanotechnology: Shaping The World Atom By Atom" (September 1999), which spelled out the vision in more detail, reminding of Eric Drexler's earlier vision.

[22] National Science and Technology Council (NSTC), (2000 July). *National Nanotechnology Initiative: The Initiative and its Implementation Plan.* Washington, D.C., p. 13 [http://www.nano.gov/nni2.pdf].

[23] The White House, Office of the Press Secretary: "President Bush Signs Nanotechnology Research and Development Act" (December 3, 2003) [http://www.whitehouse.gov/news/releases/2003/12/20031203-7.html]

[24] http://thomas.loc.gov/cgi-bin/query/C?c108:./temp/~c108PRZXRc

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) that it should 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, [my emphasis]

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.

The list of anticipated "societal concerns" is further completed 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 the 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 US policy makers want to prepare their society for more than nanotechnology. On the other hand, "societal implications" includes, according to the NSF report on *Societal Implications of Nanoscience and Nanotechnology* from 2001, also 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.

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; 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.

There is yet another political aspect that deserves 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.[25]

In addition to the symbolic competition by means of figure cosmetics, the focus on nanotechnology provides the opportunity to rearrange the landscape and strategy of research funding. In the US, where the physical sciences and the biomedical sciences have been funded separately 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,[26] will have an impact on the redistribution of responsibility and power among US agencies.

Thus, apart from the political double meaning of "societal implications" of nanotechnology (the welcome economical impact and the unwelcome public concerns), 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.

2.4 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 fast money. 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.[27] On the other hand, numerous business consultants, venture capital and investment firms are seeking a share in mediating between the manufacturing business and the private investors. Until recently, their efforts to attract private investors consisted largely in providing information via NanoBusiness Internet Portals and nanobusiness reports.[28] 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

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25 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, *Faktenbericht Forschung 2002* (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, *Nanotechnologie in Deutschland: Standortbestimmung* (published in June 2002), claiming that federal funds for nanotechnology had already been €149.2 million from 1998-2001.

26 See Mihail C. Roco & William S. Bainbridge (eds.): *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, Dordrecht: Kluwer, 2003.

27 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 http://www.nano.gov/html/funding/businessops.html)

28 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 http://www.researchandmarkets.com/search.asp?q=nanotechnology

"Stunning breakthroughs in Nanotechnology are about to transform the future of our economy and make EARLY INVESTORS RICH**"**[29]

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 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 try 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 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.[30] Three weeks later, Merrill Lynch introduced a Nanotech Stock Index at the New York Stock Exchange,[31] 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.[32] In their accompanying "research report" called "Nanotechnology: Introducing the Merrill Lynch Nanotech Index" (April 8, 2004), the investment bank argues (p.2):[33] "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.

Indeed, NSF's forecasted $1 trillion market is quoted in most nanobusiness reports, sometimes the $1 trillion appear 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 expertise along with their 250-page *The Nanotech Report 2003*, because they would have been "the first to recommend following government funding".[34] 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.

2.5 Transhumanists

Transhumanism is a quasi-religious movement of people who 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-

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29 http://www.newsletters.forbes.com/nanotech/ (June 30, 2004).

30 http://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.

31 http://www.ml.com/about/press_release/04012004-1_nanotech_index_pr.htm (June 30, 2004).

32 Marc Reisch: "A Rose By Any Other Name?" Chemical & Engineering News, Volume 82, Number 16, p. 8

33 http://www.ml.com/about/press_release/pdf/04012004_nano_index.pdf (June 30, 2004).

34 http://www.luxcapital.com/nanotech_report_b.htm (June 30, 2004).

intelligence".[35] It is quasi-religious in its members' earning for salvation, 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. 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. Indeed, it is the key technology vision on which most of transhumanism rests. First, they foresee the development of Drexler's 'assemblers'[36] 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 wishlist 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 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,[37] there is a strong moralist approach that is based on 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 potential 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 make 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 at the US

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[35] See the information on the website of the World Transhumanist Association (www.transhumanism.org); particularly informative are "The Transhumanist Declaration" (December 2002) and "The Transhumanist FAQ: A General Introduction" written by philosopher Nick Bostrom. 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 Ed Regis: *Great Mambo Chicken and the Transhuman Condition: Science Slightly over the Edge*, Reading, MA: Addison-Wesley, 1990.

[36] Eric Drexler: *Engines of Creation: The Coming Era of Nanotechnology*, New York et al: Anchor Pr., Doubleday, 1986.

[37] Extropy Institute (www.extropy.org).

National Science Foundation,[38] and Mike Treder, Director of the Center for Responsible Nanotechnology.[39] On the other hand, their existential end let them consider the means, i.e. the development of nanotechnology, much more optimistic 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, and at the same time 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 to come.

Some transhumanists, including leading figures, go further. Max More, philosopher and Chairman of the Extropy Institute, argues for replacing the precautionary principle in legislation with what he calls the "proactionary principle":[40] "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. 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".[41] 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 all taken from science fiction novels, 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.

Complementary to utopian visions, transhumanists employ distopian visions for the same end, a double argumentation that, in the case of nanotechnology, goes back to Drexler's *Engines of Creation* (1986). Since the distopian line of thoughts has forerunners in the promotion of various big military research projects, from the Manhattan Project to SDI, I start with discussing the general argument, which rests on five assumptions, before dealing with the transhumanist version.

(1) technological determinism, i.e., that the development of any envisioned technology is inevitable;

[38] Mihail C. Roco & William S. Bainbridge (eds.): *Societal Implications of Nanoscience and Nanotechnology*, Dordrecht: Kluwer, 2001; Mihail C. Roco & William S. Bainbridge (eds.): *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, Dordrecht: Kluwer, 2003.

[39] Center for Responsible Nanotechnology (www.crnano.org).

[40] Max More: "The Proactionary Principle" (2004) [www.extropy.org/proactionaryprinciple.htm (last visited June 30, 2004)].

[41] Nick Bostrom: Question 3.3 of *The Transhumanist FAQ: A General Introduction* (Version 2.1, 2003) [http://transhumanism.org/index.php/WTA/faq/].

(2) technological control over technology, i.e., that further developed technology can always control less developed technology;
(3) the ambivalence of technology, i.e., that technology can be used both for benefits and harms;
(4) the existence of evil: i.e. that evil forces will use technology for the harm of humanity;
(5) the moral superiority of the own society, i.e., that the own society will use technology only for the benefit of humanity.

From those assumptions, and only from those, follows that the own society must undertake extra efforts in technological research and development to prevent the evil forces from doing harm to humanity by technological control. While assumptions 3 and 4 might be acceptable, the other assumptions are in general rather dubious and naive, such that the conclusion is unsound.

In the transhumanist distopia of nanotechnology, the argument comes in a particular dramatic and religious manner, but politically less naive. Because transhumanist believe in the future manifestation of all their nanotechnological visions, technological determinism, a secular version of the Christian salvation determinism, is part of their belief system. The idea that further developed nanotechnology can control less developed nanotechnology is justified by envisioning just more intelligent nano-robots that establish a nanotech immune systems against other nano-robot attacks. Since they expect unimaginable benefit from the power of technology, their application of the ambivalence principle results in the fear of unimaginable harm, the extinction of all intelligent life by nanotechnology weapons, as the secular version of the Apocalypse goes. However, transhumanists, following Drexler, are to some degree skeptical about the moral superiority of their own society, have a more international perspective and generally fear the military abuses of nanotechnology anywhere, including a nanotechnological arms race. Therefore, they try to solve the dilemma by arguing that nanotechnology must be fostered in the “more responsible” countries under additional democratic or moral control. Since such control would require transparency, which would favor knowledge transfer to “less responsible” countries, the dilemma is not really solved. At this point, they argue for “rational” risk/benefit assessment by weighing the technologically determined certainty of Salvation against the likelihood of the potential Apocalypse.

2.6 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 perspective and interest focus 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 for 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 and nanotechnology. Although the distinction between business and science & technology magazines is still discernible in their mission statements, particularly in older ones, the border is increasingly blurred, so that the *smalltimes*' publishing concept might be forward-looking. The convergence of business magazines and science & technology magazines suggests that people interested in business are increasingly also 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 type 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 a new nanocenter, 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 19% 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 potential toxicity of buckyballs on fishes; a British study on the possible transfer of nanoparticles from a pregnant rat to the fetus, 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.[42]

2.7 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 with the few following remarks, the more as this group comprises many different disciplines.[43] 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 development of nanotechnology changes 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

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[42] 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 J. Schummer: "Reading Nano: The Public Interest in Nanotechnology as Reflected in Book Purchase Patterns", *Public Understanding of Science* (forthcoming).

[43] For a bibliography, see Schummer, J.: 2004d, 'Bibliography of Nano-Science and Technology Studies", in: D. Baird, A. Nordmann & J. Schummer (Eds.), *Discovering the Nanoscale*, IOS Press, Amsterdam (forthcoming).

implications […] efforts […] to promote a new generation of skilled workers”. And the US Nanotechnology bill 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 technology. 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. 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 funds 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. The expertise here rests not so much on talkshow 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.

3. The Mutual Impact of Meanings: Semantic dynamics

Now that we have identified several interest groups and their various meanings of “societal and ethical implications of nanotechnology”, we can analyze their mutual impacts. It should be noted, however, 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 analyze. 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 constrained 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 novels before, and for some impact on scientists, including the posthumous founding figure Richard Feynman.

The visionary (software) engineers have in turn strong impact on more 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 influence also the meaning of this group.

Nanoscientists, due to their underdeveloped notion of “societal and ethical implications”, are less influential. However, to some degree they have a discernable impact on the media/public and on politicians, as the recent political turn towards more specified research projects illustrates.

Toxicologists and environmental scientists have a strong impact on the media/public. Representing the science-based side of concerns, their ideas are also taken by cultural and social scientists.

Policy makers 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.

The impact of transhumanists is again difficult to estimate. Since we find transhumanists particularly among visionary engineers and also among science fiction authors and in governmental agencies, it is reasonable to assume that they impact these groups accordingly. In addition, the explicitly mentioning of transhumanist vision in the US nanotechnology bill suggests that the impact on policy maker is not insignificant.

For the media/public in a democracy we may, despite the current lack of evidence, assume that they have a strong impact on politicians. In addition, the strong focus of current nanotechnology reports on business suggests some impact on business.

Finally, the sophisticated meaning of “societal and ethical implications” of cultural and social scientists has no discernable impact on any of the other groups up to now. The only indirect impact seems to be on transhumanists. 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.

It is clear that the analysis of mutual impacts of meanings is thus far only preliminary and that further research can provide more evidence of impacts and a more sophisticated fine-tuning. Given these limitations, we may summarize the results by a simplistic mathematical model in the form of an impact matrix with discernable impacts described by factor 1 and strong impacts by factor 2 (see Table 2).

Table 2. 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		2					2	1	
Vis. Engineers	2		1		1	2	2		
NanoScientists					1			1	
Tox. & Env. Sci.								2	1
Politicians			2			2		1	
Business		1	1		2			2	
Transhumanists	1	2			2				
Media / Public					2	1			
Cult. & Soc. Sci.							1		

The advantage of such a mathematical model is that it allows applying algorithmic tools of social network analysis for the understanding of social dynamics.[44] The simplest analysis consists in adding up the impact factors from each group (Out-Degree) and to each group (In-Degree) (see Table 3), which are raw measures for the total influence and the total susceptibility of each group. In turns out that visionary engineers are the most influential group to be followed by business, transhumanists, politicians, and science fiction authors. On the other hand, politicians and the media/public are most susceptible to meaning impacts, to be followed by business, transhumanists and visionary engineers, whereas toxicological, environmental, cultural, and social scientists each have strongly autonomous meanings of “societal and ethical implications”. More sophisticated network analysis applies iterative algorithms, such that, for instance, the impacts on other groups are weighted by the weighted impacts these other groups each have on other groups (Impact Status Centrality after Katz[45]). In our case, the sophisticated analysis supports the simple out-degree analysis (Table 3). Visionary Engineers are clearly the most influential group to be followed in decreasing order by business, transhumanists, science fiction authors, and politicians. Another formal index is the “Information Centrality” that, simply speaking, combines the influence and susceptibility of each group and can be considered a measure for mediating meaning. (More technically, the algorithm first determines all possible paths of influence for each ordered pair of groups in the total network and then ranks each group according to the number of paths that go through it.) It turns out that politicians are the most active mediators, to be followed by the media, visionary engineers, transhumanists, and business.

Table 3: Formal Analysis of the Network of Interest Groups

	Out-Degree	In-Degree	Impact Status Centrality (Katz)	Information Centrality
SciFi-Authors	5	3	0.779	2.484
Vis. Engineers	8	5	1.143	3.011
NanoScientists	2	4	0.257	2.511
Tox. & Env. Sci.	3	0	0.336	1.855
Politicians	5	8	0.633	3.168
Business	6	5	0.799	2.872
Transhumanists	5	5	0.783	2.921
Media / Public	3	7	0.425	3.112
Cult. & Soc. Sci.	1	1	0.150	1.478

Since influence and susceptibility are dynamic properties that describe tendencies, we can use the data to develop a sketchy dynamic model of the debate on “social and ethical implications of nanotechnology”. Roughly speaking, with the exception of the media, the most influential groups are also the most susceptible groups, and these groups mostly influence each other, so that they make up a relatively closed cluster of mutual influence. I call the members of this cluster – consisting of politicians, visionary engineers, business, and transhumanists – the *semantic leaders*. Cultural and social scientists, toxicological and environmental scientists, and nanoscientists are rather disconnected from the cluster, with only indirect influence through the media. The media/public, though being very susceptible for meanings from various groups, has some influence on politicians and business, of which the most important one certainly is the mediation of concerns from toxicological and environmental scientists to

[44] For introductions to social network analysis, see for instance Wasserman, S., & Faust, K.: 1994, *Social Network Analysis: Methods and Applications*. Cambridge, MA: Cambridge University Press; and Scott, J.: 1994, *Social Network Analysis: a Handbook*, London: Sage.

[45] Katz, L.: 1953, ‘A new status index derived from sociometric data analysis’. *Psychometrika*, **18**, 34-43.

politicians. Because the mediating role of science fiction authors is largely restricted to mediating ideas back and forth between visionary engineers and transhumanists, their overall impact on the cluster is limited.

The model suggests that in the foreseeable future, unless major concerns from toxicological and environmental scientists influence politicians and business via the media/public, the meaning of “social and ethical implications of nanotechnology” will be largely negotiated among the semantic leaders. Although each of the semantic leaders have their own specific interests, politicians, visionary engineers, business people, and transhumanists share and exchange much of their meanings of “social and ethical implications of nanotechnology”. They all have grand visions about how nanotechnology will change society in unprecedented way and differ only in details, how radical the change will be and how important business is. In addition, they all share the strong concern that any critical concerns from other members or groups of society might diminish their visionary future. The model suggests that the semantic leaders have formed a robust visionary alliance that is rather unsusceptible for both the more realistic views of natural scientists and the more sophisticated meanings of “social and ethical implications of nanotechnology” by cultural and social scientists.

4. Conclusion: An Outlook into the Near Future

Provided that the dynamic model is, despite its simplifications, correct in identifying the visionary alliance of the semantic leaders, it is not very difficult to predict some likely developments. And since most about nanotechnology is about the future, I will conclude with an outlook into the near future that is based on the dynamic model, 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 are 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 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 is very 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 nanoparticles will probably 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 very 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, 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.[46] 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".[47] 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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[46] See for instance, Ogrinc, W.H.L.: "Western Society and Alchemy from 1200 to 1500", *Journal of Medieval History*, **6** (1980), 103-133; Obrist, B.: 'Die Alchemie in der mittelalterlichen Gesellschaft', in: Chr. Meinel (ed.), *Die Alchemie in der europäischen Kultur- und Wissenschaftsgeschichte*, Harrassowitz, Wiesbaden, 1986, pp. 33-59. Schummer, J.: "The Notion of Nature in Chemistry", *Studies in History and Philosophy of Science*, **34** (2003), 705-736.

[47] Schummer, J.: "Historical Roots of the 'Mad Scientist': Chemists in 19th-century Literature", *Ambix* (forthcoming).