Nanotechnology: Constructing a Proactive Science Policy for Democracy

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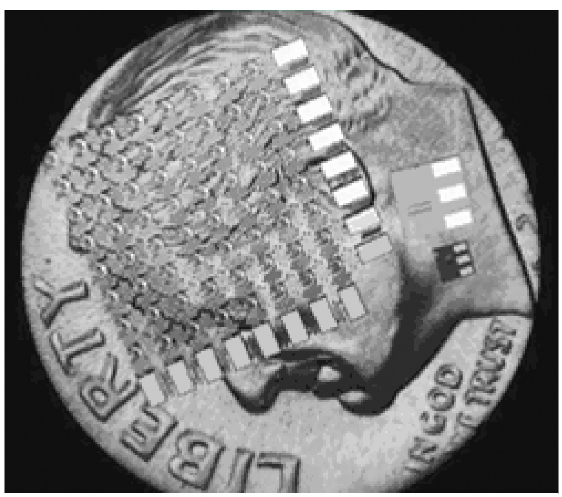
Already crowned "the next industrial revolution," the emerging field of nanotechnology has the potential to remake society anew. Manotechnology, if we so choose, also offers a second potential: to remake the scientific enterprise as we know it, by incorporating it within a new, democratic framework for science policy.

Given that science is a human good, how does society decide what outcomes science should achieve (*1*)? No individual should be able to guide science toward their subjective 'good', and while scientists may know the best direction for their own individual research, the only mechanism worthy of directing the scientific enterprise as a whole is a democratic one. Developments within science can have a profound impact on society, and research on the societal implications of science can uncover many substantial interconnections. Changing the structure of science policies and funding can significantly impact the outcomes science achieves. To better allow for democracy to decide what good science should achieve, a serious and proactive assessment of the possible implications of scientific work is needed in order to make informed, democratic decisions (*2*).



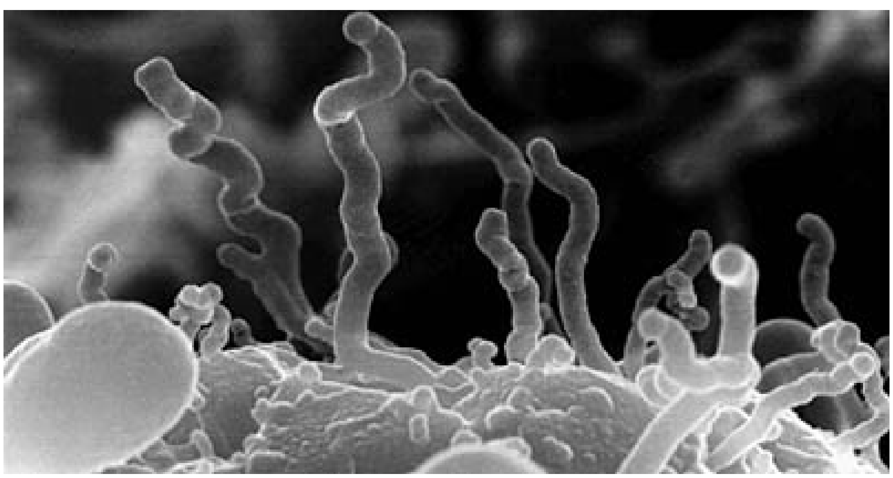
Democratizing science is about a systematic reform in science policy to incorporate public values in the science policy-making process, not about instituting a popular vote on what scientists should maintain. Recent opportunities have paved the way for a practical complement to the ideal of democratized science. New legislation to support nanotechnology mandates research into the societal and ethical implications of nanotechnology (SEIN). One very promising approach to SEIN is "Real-Time Technology Assessment" (RTTA) (*3*). If undertaken properly, RTTA-based research could be a limited but important first step toward the democratization of science because it seeks to cultivate an early assessment of scientific projects, and to apply a rigorous social science assessment in conjunction with practicing nanoscale scientists and engineers. Conventional science policy may yield good outcomes, but this is almost accidental, not intentional. By enabling a more democratized approach to science policy, we can aspire to better outcomes from science for society.

Nanotechnology: Science, Technology, and Policy-making

Because it is new and less bound in tradition, nanotechnology is ripe for implementing a new approach to science policy and, through RTTA-driven SEIN, the drive to create the tools for a more democratic governance of science is underway. The creation of a new approach to science and science policy begins with a solid understanding of the science itself, and the basic science behind nanotechnology is fascinating. Nanotechnology is science and engineering work at the level of 10^{-9} meters, or 1/40000^{th} the width of a human hair, where the basic properties of materials are defined. Out of the total US public research and development budget of 135 billion dollars, the 2006 US nanotechnology research budget stands at a relatively impressive one billion dollars (*4, 5*). The research that is described by the word nanotechnology is broad in scope. Some focus on bionanotechnology, where there are remarkable new possibilities in the traditional fields of biology and medicine, such as the creation of nanoscale drug delivery modules that can be used to image and treat disease infections (*6*). Materials nanotechnology groups have been working on the creation of new materials, some with ultra-high strength and low-weight properties that result from new nanoscale structuring (*7*). Overall, a variety of nanoscale, cutting edge research programs from a mix of traditional disciplines such as materials science, microbiology, physics, semiconductor science and mechanical engineering are being relabeled as nanotechnology.

Like other "revolutions," nanotechnology has its own creation mythology, where the nano-dream began with famed physicist Richard Feynman. In his 1956 talk, "There's Plenty of Room at the Bottom", Feynman described a world where the entire Encyclopedia Britannica could be written on the head of a pin (*8*). The first popular use of the word nanotechnology came with Eric Drexler's 1986 book Engines of Creation (*9*). There, Drexler focused on the possibility for molecular nanotechnology, and detailed a vision for creating robotic control at the nano-level. His account did more than merely foretell a type of engineering; he speculated about potential societal outcomes of molecular nanotechnology. The most infamous of these scenarios is Drexler's depiction of self-replicating nanobots that could consume the world, made infamous by Michael Crichton's characterization of out-of-control nanobots in his sci-fi bestseller Prey (*10*).

In Washington D.C, the political creation of nanotechnology's funding is also mythologized. Key policymakers like Mikhail Roco, and his colleague, William Bainbridge have lobbied for nanotechnology funding since the mid-1990's as part of a federal working group (*11*). Their efforts reached their greatest success with the 2000 creation of the US National Nanotechnology Initiative, which was the first of several congressional acts sponsoring nanotechnology. Henceforth, there would be a continuing 'nano' presence on the national scene, and Roco was named director of the National Nanotechnology Initiative. Political opposition to nanotechnology became organized during this time as well. The 2000 *Wired* magazine article "Does the Future Really Need Us?" by Bill Joy highlights the potential dual-use of nanotechnology, particularly regarding fears about the powers of molecular nanotechnology, as Drexler and Crichton have envisioned (*12*). Given the potentially catastrophic dangers of nanotechnology, Joy argued that the science might be too dangerous for human use, and that the research should be abandoned. Scientists affiliated with the National Nanotechnology Initiative battled to convince the public of the impossibility of molecular nanotechnology and other potentially dangerous nanotechnology developments. Despite all this, the debate largely glossed over Joy's essential logic: if an emerging science could lead to harm to society, then it should be avoided (*13*).



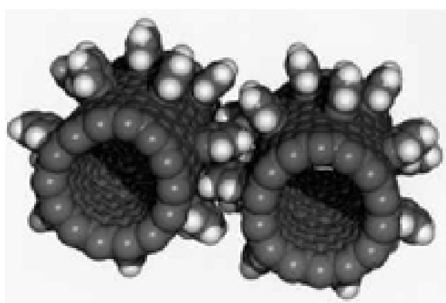
Many of these questions directly relate to a choice about what good science should achieve. The current state of nanotechnology science policy may be oriented toward the values of a few individuals. This is because one key mission of the US nanotechnology research and development program has been to establish the convergence of nanotechnology, biotechnology, information technology, and cognitive science (NBIC) as a central focus of science and technology (*14*). In a speech reflecting his personal views, nanotechnology policy entrepreneur William Bainbridge described this "convergionist approach" for nanotechnology, and described his two goals of personality enhancement and "personality capture," where "information about a person's mental and emotional functioning [is captured] into a computer...system" to create a simulation of a human (*15*). Although many might not associate nanotechnology with things such as human enhancement, significant National Science Foundation-sponsored nanotechnology research is working toward these NBIC goals (*14*). Many describe this pursuit of exceeding humanity's physical and social limitations as raising serious questions about the nature of human beings. Transhumanism, or the attempt to enhance human abilities and to potentially escape mortality, may be waiting in the wings behind particular developments in nanotechnology.

While transhumanism is seemingly welcomed and supported by science policy entrepreneurs like William Bainbridge and Mikhail Roco, the American public has yet to recognize that US science policy has been partially oriented toward establishing a nanotechnology enabled transhuman future (*14*). When one-third of all US science and technology research is funded by the government, often setting the precedent for private investment, the potential to concentrate public science policy-making in the hands of a few is alarming (*16*). Bainbridge speaks as though transhuman outcomes are inherently good, but the radical potential of a transhuman future demands that this conclusion be examined more seriously. This deliberation is part of the goal for a democratized science.

Defining the Societal and Ethical Implications of Nanotechnology

Nanotechnology has been supported by public funding since its inception, and many of the questions surrounding nanotechnology are directly relevant for a society that seeks to guide itself. To better connect science and democracy, there must be a way for society to guide the developments of science. SEIN research is one potential tool that can be used in the democratization of science, but the conception of SEIN must be structured properly.

The definition of the social and ethical implications of nanotechnology, or of any science, must be mindful of the societal context. This broader context is often overshadowed by a focus on tangible environmental and toxicological impacts of potential nanotechnologies. Researching these possibilities is important for ensuring safety, and most policymakers agree that the government should ensure the safety of emerging nanotechnologies. However, many scientists exclusively identify environmental and toxicological effects as the only possible social implications. This identification is unfortunately narrow and in some ways naïve. Science impacts broad societal concerns, such as inequity and civil liberty. Insightful analyses have shown a complex and interdependent relationship between technology and society, with each having a substantial influence on the other (*17*, *18*). One can clearly see how the threat of nuclear weapons could have broad social implications, but others have convincingly argued that even mundane technologies, such as basic architectural structures, can likewise have a profound effect on an individual's sense of political identity (*19*). The conception of SEIN needs to pay as much attention to the subtle influences of technology as it does to the tangible safety risks.



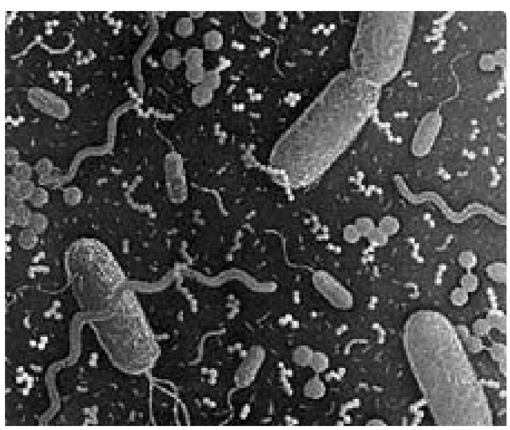
For nanotechnology, what could the social implications of Bainbridge's NBIC-enabled goals of personality capture and human enhancement be? Some object to the alteration of human traits by potential NBIC technologies as removing humanity from an essential mortal core. Personality capture could potentially eliminate the traditional notions about life and death by enabling a simulated personality to live on forever. There are also broad social issues to consider: What happens if access to these abilities is restricted to the richest members of developed nations? Would social classes of rich and poor be further separated by transhuman capabilities? And if NBIC personality capture is possible, what would the existence of digitized transhumans do to our conceptions of individual rights? Potential social conflicts loom in the background of a potential NBIC convergence, and the ability for society to impact the direction of this research seems to decrease once technologies are on the market. Awareness of such SEIN-related issues should be used to foster informed debate about why NBIC research is done, especially when public funding is supporting it.

The democratizing potential of SEIN research can be seen in the terms of the 2003 21st Century Nanotechnology Research and Development Act (Nano Act), which authorizes much of the SEIN research. The act calls for "ensuring that 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, are considered during the development of nanotechnology" (*20*). By the legislation, SEIN is intended to have a broad scope in investigating a range of issues before the underlying technology comes to market. Furthermore, it calls to "integrat[e] research on societal, ethical, and environmental concerns with nanotechnology research and development, and ensur[e] that advances in nanotechnology bring about improvements in quality of life for all Americans". This is a broad mandate, but the importance of integration is to become aware of significant issues early enough such that meaningful decisions can be made about how to handle the direction of scientific research. The NBIC example shows how tangible technologies may be analyzed prior to their full development, and can be used to imagine complex results from numerous areas of science. This forethought and understanding can be used as the basis for enabling better democratic decision making about the science well before the technologies reach the market.

As NBIC is only one of many research paths within the nanotechnology umbrella, the concept of SEIN will be very diverse. Surveillance might be one issue within nanotechnology development. Research being done at Berkeley is typical of other efforts to create undetectable nano-sized surveillance devices (*21*). Such "nanodust" could alter the character of privacy in public spaces, as surveillance can become undetectable over large areas. Other nanotechnologies seem poised to drastically alter social structure. Nanomaterials research is enabling the creation of fundamentally new macro-scale properties by way of manipulating materials at the atomic level. This could enable a transformation of industry as it is known today. Often ignored or hidden, military nanotechnologies could revolutionize war. Alarmingly, much of the nanotechnology budget goes to the military, for projects ranging from new, powerful weapons to super-soldier technologies (*22*). Other questions surrounding the societal context of nanotechnology exist. Many worry that the benefits of nanotechnology will be used to exclusively benefit developed nations, or that nanotechnology will cause the acceleration of industrialized economies to a speed that the developing world cannot catch up to (*23*).

The societal and ethical implications of nanotechnology are both deep and broad, but the utility and worth of SEIN research is not always clear. Some SEIN research might have immediate practical uses on its own, but it is best actualized by a guiding framework designed to encourage democratic deliberation. By including meaningful reflection on SEIN early in nanotechnology's development, SEIN research can be used to highlight unforeseen opportunities to guide the science toward socially beneficial outcomes, and it can be used to help prevent and mitigate inequitable outcomes and disasters.

The directors of Arizona State University's National Nanotechnology Initiative-funded Center for Nanotechnology in Society (CNS-ASU) have termed such a framework "Real-Time Technology Assessment" (RTTA) (*3*). Through empirical, conceptual, and historical studies as well as public engagement exercises, the goals of the methodology are: to assess possible societal impacts and outcomes; develop deliberative processes to identify potential impacts and chart paths to enhance desirable impacts and mitigate undesirable ones; and evaluate how the research agenda evolves. By integrating these processes within a proven social science approach, CNS-ASU's analysis is structured to aid in the process of making choices about technology. "The only novelty of this process... is rendering explicit and self-aware the currently implicit and unconscious process of co-production" between science and society (*3*). Further founding their assessment approach, CNS-ASU has the ability to work from a partnership with ASU's Biodesign Institute, which has strong resources in nanoscale science and technology.



Real-time technology assessment is one of many paths that have been indirectly established by the Nano Act. While SEIN research is mandated for all major nanocenters, not all such research embodies a proactive, real-time focus. Many individual nanotechnology centers have a SEIN committee, but their research agendas are independent and they are not networked together in any systematic way. Beyond the Nanotechnology in Society Network, which includes CNS-ASU and another CNS at University of California at Santa Barbra, SEIN research is decentralized and unguided. Perhaps SEIN will become a lost opportunity, but the spirit of the Nano Act, as seen by its text and legislative history, provides a foundation to enable an ambitious view of SEIN. To understand why many may want SEIN to be limited in its scope, one must confront SEIN's framing experience.

SEIN's Shadow: The Human Genome Project and Technodeterminism

From the inception of the National Science Foundation, there is a long history of scientists attempting to protect the scientific enterprise from the realm of democratic control (*24*). One hope for a change away from this history ended up partially reinforcing the insular practice of science. The Human Genome Project's Ethical, Legal, and Social Issues program (ELSI) has been seen as the direct ancestor of SEIN. The Human Genome Project was a concerted attempt to research and sequence the entire human genetic code, and ELSI is the only other major research effort dedicated to societal implications. Unlike SEIN research, ELSI benefited from having a centralized organization, but the program was without a forward-looking direction analogous to real-time technology assessment. ELSI chronicler Robert Cook-Deegan has stated that the intent of ELSI was not to influence policy in a democratic framing, but to react to understand the changes after they happen (*25*). ELSI produced some valuable contributions to understanding the effects of the Human Genome Project, but overall it was too reactive and not sufficiently proactive.

If the ELSI program was intended to merely pave the way for the progress of science, it would be an intellectual fit for much of US science policy. The founding US science policy document, Vannevar Bush's <u>Science: The Endless Frontier</u>, argued that research organizations should be controlled exclusively by scientists. Bush's justification for funding relies on the premise that all science, basic or applied, inevitably leads to public good. For Bush, the progress of science requires guidance by experts from within science, entailing that public input should be avoided (*26*). While the ELSI program offers a forum for the social issues surrounding science to be addressed, it does not seek to change Bush's scientistexclusive decision-making process. No matter the concerns raised by ELSI, the research would go on, and society would have to adjust.

Many scholars of science and technology have labeled this attitude "technodeterminism". There is an entire academic literature dedicated to showing that the simple answers given by technodeterminism are not sufficient for explaining how science actually works (*27*, *28*). The Manhattan and Apollo projects are instances where social direction of the scientific enterprise was explicit from the beginning, and where political guidance of science was effective. There are other examples where public participation early on in scientific projects led to appropriate outcomes (*3*, *29*). Following the conclusions of this literature would have led ELSI along the deliberative RTTA-based approach that has been sketched. That ELSI didn't follow this more proactive and democratic path is regrettable, but understandable, given the general technodeterminist leanings of science policy.

ELSI has been severely criticized, in part due to an increased understanding of the failings of technodeterminism. In a 2001 editorial, *NatureGenetics* called the ELSI program a practice of 'ethics as usual' that too often supported scientific practices instead of advocating for societal concerns (*30*). This dissatisfaction is an incremental and limited push for a potentially democratized science. The desire for a mature and democratically oriented science policy was visibly present at the congressional hearings for the 2003 Nano Act. In highly influential testimony to the House Science committee surrounding the passage of the nanotechnology act, science and technology scholar Langdon Winner said "technological change is never foreordained, the future never foreclosed. Real choices need to be identified, studied, and acted upon despite recurring efforts to say, 'Sorry, you're too late. Your participation won't be needed, thanks'" (*31*). In Winner's sense, ELSI was too friendly to the scientific enterprise, and failed to generate critical, meaningful, proactive deliberation. Many of ELSI's advocates supported SEIN in order to get more of the same.

Winner's influence on the SEIN legislation provides hope that SEIN will avoid a technodeterminist position, but the vision for SEIN research expressed by the Nano Act has the potential to go either way. The technodeterminist approach to nanotechnology has clear influences on the Nano Act, but an ambitious and expanded vision for SEIN does as well. In an analysis by Erik Fisher and Roop Mahajan, both potentially conflicting themes are seen to be written into the act (*32*). The majority of the Nano Act's provisions are focused on a perceived global research race for the supremacy of nanotechnology. The goal is to develop as fast as possible, and thus the majority of the text is oriented toward an outcome that technodeterminists would find highly agreeable. On the other hand, Fisher and Mahajan identify a "heightened awareness of the role public concerns and perceptions can play in the adoption of new technologies... [and] extraordinary legislative language requiring research on societal concerns to be integrated into nanotechnology research and development." Despite potentially technodeterminist leanings, the Nano Act has done more to open the possibility for the integration of social implications research with basic research than any prior legislation, and this can be interpreted in the democratically deliberative fashion of ASU's real-time technology assessment. This proactive interpretation of the legislation should be embraced for its apt understanding of the moral good of science and because it can serve as the beginning of a more democratized science.

Democratizing Science: The Moral Imperative for an Expanded Vision of SEIN

Given the implicit conflict within the Nano Act over the role of SEIN, it is imperative to argue for the expanded vision for SEIN. When examined under close scrutiny, the technodeterminist position that scientists alone have the authority to guide the organization of science falls apart. In <u>Science, Truth and Democracy</u>, philosopher Philip Kitcher explores the notion that the scientific pursuit of truth should be preserved against moral and ethical concerns external to science (*1*, *33*). Within basic science, there are situations where the pursuit of some truths might be questioned, either when there may be a moral objection to a particular research project or a dispute as to whether the funding for science should be spent elsewhere. One example of a moral objection could be research on genetic differences between ethnic groups that could confirm the beliefs of racists (*34*). Even though this research could be used for persecution, technodeterminists argue that understanding racial genetic differences is of greater importance, i.e. that the truths being pursued are more significant than the social risks. No one argues that all possible truths are significant such that they can override societal considerations: for instance, no one would sacrifice human life in order to learn the number of pebbles of sand on a beach. But technodeterminists may hold that certain truths are *objectively* significant, thus outweighing any one group's objections. The science is said to be significant enough that research must be carried out. But what justification is there for relying on an objective notion of epistemic significance?

As Kitcher shows, the idea that scientists are pursuing some objectively important truths is questionable (*35*). Despite many attempts, the idea of a universal conception of scientific merit is unattainable, and Kitcher shows that scientific significance is constructed from a social origin. There can be no reliance on an overriding conception of the pursuit of truth to justify all scientific research, and research should be examined in terms of *both* its potential practical and epistemic benefits. Beyond the question of whether particular research is moral, the cost of pursuing truth must be evaluated against opportunities lost: should society fund basic science, or pursue more direct social goods, or both? Why fund research on a multimillion dollar superconducting supercollider when millions of people live without potable water? Both basic and applied scientific research can generate good outcomes for society, but the risks of failure or of harmful repercussions should be evaluated by a democratic process. Because the epistemic values of scientists stem from the same social origin as other concerns, there is no ground for advocating the supremacy of scientific authority. Thus, even within basic research, the moral value of scientific work is an important human good, but it is a good on equal standing to all aspects of society.

How does society decide what good science should achieve? For Kitcher, the mechanism least likely to engage in prejudice is a democratized science (*36*). In an ideal democracy, each member is committed to the process, and will not disenfranchise individual groups. Instead of trying to force the values of scientists onto the public, representatives would instead have their natural preferences tutored in the relevant science. Most importantly, each member would be tutored in the epistemic and practical significance values of the entire body, thus allowing for a sharing of social context. If all deliberators were sincere, this shared information would allow an open debate for and assembly of a list of objectives for science that well reflects society. Kitcher calls this ideal 'well-ordered science', and this deliberation is used to decide what research should be funded, what the most efficient yet moral research path is, and how to use the results of research.

Many scientists recoil at the idea of an 'uneducated' public having an input on what research is done. Moreover, a drastic societal shift to the ideal of well-ordered science would be impractical, and if mandated all at once it would impose democracy onto science in a way that would be disastrous. However, Kitcher has no interest in 'vulgar democracy', whereby an underinformed majority makes decisions on the basis of gut-feelings. Further, Kitcher recognizes the dramatic practical difficulties of public involvement in well-ordered science. So it is important to consider well-ordered science as a philosophical ideal to be aspired to, to help clarify the intent of and justification for a more practical approach towards introducing democracy within science policy. Following the ideal sense, it becomes clear that a democratized science shouldn't involve subjecting science to the supremacy of an uninformed public. It should instead allow for the embedded values in all parts of science to become clearer, allowing for scientific research programs to better reflect the ends society wants science to achieve. A society fully oriented toward well-ordered science would have the publicly funded scientific community well in tune with the needs of humanity, directing its work to societal needs.

That Kitcher's ideal is philosophical in character does not mean that it should not be used to advocate for a more democratized science policy (*37*). Kitcher's ideal is designed to help justify and guide a more developed political approach towards improving science policy incrementally. In the case of CNS-ASU's real-time technology assessment, the ability to generate information about possible societal outcomes early enough to enable public and policymakers to make decisions is a step toward democratization (*3*). In particular, CNS-ASU's attempts at scenario-building are designed to create realistic visions of nanotechnological developments – and their implications – that can be used early enough to foster some of the ideal deliberation to which Kitcher aspires. The methodology has also been supported by social science literature and past practices, and the investigation is strengthened by a strong relationship with nanoscience resources at ASU (*3*). There is a variety of other ways in which democratic science policy changes can be practically implemented, all of which have the potential to achieve some of the societal, moral, and even philosophical benefits that Kitcher describes (*2*).

Conclusion

Since science is a human good, democracy has the potential to most fairly determine what good to hope for, and SEIN might help achieve the goal to order science more justly and more effectively. However impractical the philosophical ideal of a fully democratized science, RTTA-driven SEIN offers a way to create a realistic, political method for democratizing science policy (at least in this nano-cosmic case, if you will, but likely with more general applicability). Through real-time technology assessment, SEIN can be proactive in a way that ELSI never was, and as such SEIN can be viewed as an experiment to test the potential worth of democratized science. The claim that proactive democratic deliberation using SEIN could lead to better social outcomes needs to be proven in experience. If successful, work on SEIN and real-time technology assessment could become the practical complement to Kitcher's philosophical ideal, and should then be emulated throughout science policy. With an aim to revolutionize science policy, research on SEIN should be used to enable a proactive approach to science policy that can allow for a more democratized science.

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Page 49: http://nai.arc.nasa.gov/news_stories/news_detail.cfm?article=old/small_life.htm
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