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National Citizens' Technology Forum Report

National Citizens' Technology Forum: Nanotechnologies and Human Enhancement

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EXECUTIVE SUMMARY

Many observers believe that the "converging technologies" of nanotechnology, biotechnology, information technologies, and cognitive science (NBIC) could lead to radical and pervasive enhancements of human abilities. Both supporters and critics of NBIC technologies acknowledge that their continued development and deployment portend dramatic social and cultural challenges. Stakeholders see a need for *informed citizen input* early in the process of developing such technologies. Indeed, the legislation that authorizes the US National Nanotechnology Initiative (P.L. 108-93) speaks to the importance of public input in decision making about such research and development.

This report discusses the results of one major effort at public input. In March 2008, the Center for Nanotechnology in Society at Arizona State University (CNS-ASU) and its collaborators at North Carolina State University held the nation's first "National Citizens' Technology Forum" (NCTF), on the topic of nanotechnology and human enhancement. Organizers selected from a broad pool of applicants a diverse and roughly representative group of seventy-four citizens to participate at six geographically distinct sites across the country. Participants received a sixty-one page background document – vetted by experts – to read prior to deliberating. They also completed a pre-test questionnaire to record their initial attitudes and understandings of the topic. They deliberated face-to-face in their respective geographic groups for one weekend at the beginning of the month, and they deliberated electronically across their geographic groups in nine, two-hour sessions during the rest of the month. Electronic deliberations included question-and-answer sessions with a diverse group of topical experts. The NCTF concluded with a second face-to-face deliberation at each site. Participants drafted reports that represented the consensus of their local groups, and they completed a post-test questionnaire to record their perspectives on the NCTF and any changes in their attitudes and understandings.

Findings from the reports include:

- Unanimous support (six of six sites) among sites regarding
  - concern over the effectiveness of regulations for NBIC technologies, and
  - the need to provide public information, including more public deliberative activities and K-12 education, about NBIC technologies;
- Near-unanimous support (five of six sites) among sites regarding
  - concern about the equitable distribution of new enhancement technologies,
  - the greater importance of therapeutic over enhancement research and the important role that stakeholders might play in setting that research agenda,
  - the need for careful monitoring of such technologies and the development of international safety standards for them, and
  - the development of such technologies to maximize their benefits with both public and private investment;
- majority support (four of six sites) among the sites regarding
  - formal inclusion of ethicists and ethical considerations into decision-making for NBIC technologies;

    - the careful protection of individual privacy in the development and deployment of these technologies; and
    - the potentially problematic role of health insurance in limiting access to new enhancement technologies; and
- split support (three of six sites) among the sites regarding
    - concerns that NBIC technologies might fall into the hands of terrorists or have other unanticipated military applications,
    - concerns about potential environmental consequences, and
    - ensuring the protection of civil liberties and free choice – particularly the choice to refuse enhancements.

Findings about the participants' views on human enhancement technologies from the pre- and post-test questionnaires include:

- reduced certainty about the benefits of human enhancement technologies;
- increased worry about the affordability of NBIC enhancements and overwhelming support for the government to guarantee access to them if they prove too expensive for the average American;
- reduced, but still strong, support for publicly funded research for developing human enhancement technologies;
- conflicting emotions – continued, extensive hope and increased worry – about NBIC developments;
- opposition to many particular kinds of hypothetic human enhancements as described in the background literature.

Findings about the participants' experience on the NCTF process from the pre- and post-test questionnaires include:

- significant increases in the percentage of participants who hold opinions about NBIC technologies;
- significant substantive learning by participants about the details of nanotechnology and human enhancement technologies;
- very high levels of individual support for the conclusions of the respective geographic groups;
- increased feelings of efficacy and trust as a result of participants' role in the NCTF; and
- changes in preferences from on-line mediated deliberations to face-to-face deliberations.

We conclude that average citizens want to be involved in the technological decisions that might end up shaping their lives. Citizens remain strongly supportive of research that might lead even to transformational technologies, provided that reliable information about and attentive and trustworthy oversight of their development exists. Such information and oversight should not be restricted to environmental health and safety but should include social risks such as equity, access, and civil rights. With the appropriate information and access to experts, citizens are capable of generating thoughtful, informed, and deliberative analyses that deserve the attention of decision makers.

INTRODUCTION

A new area of technological change has been emerging onto the agendas of decision makers around the globe: the "converging technologies" of nanotechnology, biotechnology, information technologies, and cognitive science (NBIC). Many observers believe that these new technologies could lead to radical and pervasive enhancements of human abilities. Some visionaries expect NBIC technologies to dramatically enhance strength and endurance, alleviate or eliminate pain, improve or restore sight and hearing, enhance memory, speed information processing, spark artistic expression, and extend life.

Some anticipate, however, significant social change as these technologies move into widespread use, and many are concerned about public reactions them: What would relationships between "enhanced" and "un-enhanced" people in society be like? What does fairness mean when previously immutable aspects of a person's abilities are alterable? What would significantly increased life expectancy do to families, to work, to cultural continuity and innovation, and to society more generally?

These concerns have led to a flurry of interest among scholars, policymakers, and interest groups both in the United States and Europe. A number of committees, conferences, and scholars have generated in-depth reports about human enhancement technologies in general and NBIC implications in particular (see p. 12 for Selected Further Readings). Despite their disagreements on the prospective value of these new technologies, both supporters and critics of NBIC acknowledge that their continued development and deployment portend dramatic and powerful social and cultural challenges.

Such promises and challenges raise the stakes for the development and introduction of NBIC technologies, and many people across government, business, academe, and public interest and advocacy groups see a great need for *informed citizen input* early in the process of developing such potentially revolutionary technologies. With numerous examples of major technologies having become entangled in divisive political conflict and legal action—e.g., nuclear energy and genetically modified foods—decision makers are often eager to find ways to elicit the values and concerns of ordinary people and incorporate them into the process of developing these technologies. Indeed, the federal legislation that authorizes much of the US National Nanotechnology Initiative (Public Law 108-93) speaks to importance of public input in decision making about nanotechnology research and development.

CONSENSUS CONFERENCES AND CITIZENS' TECHNOLOGY FORUMS

In recent decades, new techniques for eliciting informed, deliberative public opinion have been developed and used in several countries. These techniques are often more helpful than traditional public opinion polls when the topics of concern are those, like emerging technologies, about which the public has initially very modest levels of information.

One of these practices, developed in Denmark and known as a "Consensus Conference," involves recruiting ordinary, non-expert citizens, providing them with background information and access to experts on the particular topic, and assisting them as they deliberate toward a set of agreed-to recommendations. The Danish Parliament's Board of Technology, which organizes the consensus conferences, helps communicate the recommendations to the parliament, the press, and the public.

Over the past ten years, a technique based on the Danish consensus conferences – called the "Citizens' Technology Forum" (CTF) – has been developed by scholars at North Carolina State University for use in the American context. To the original Danish model, the CTF adds the Internet as a mode of interaction, in addition to face-to-face interactions, among the citizen participants. On-line communication allows deliberations involving multiple groups of citizens in multiple geographic locations – a crucial innovation if such a process is to take root across a country that spans a continent and has multiple population centers, compared to one roughly twice the size of Massachusetts with one central city.

The CTFs conducted in the US, which have examined topics including genetically modified foods, climate change, and nanotechnology, have usually been run in university contexts as research and demonstration projects and have not been part of official policy making bodies. As part of this research orientation, many CTFs have included questionnaires administered to the participants before and after their participation, allowing researchers to collect significant amounts of data about processes of learning, attitude changes, and personal interactions in which citizens engage.

THE NATIONAL CITIZENS' TECHNOLOGY FORUM

In March 2008, the first National Citizens' Technology Forum (NCTF) took place. It employed the basic CTF process, but this time involved six locations across the country, and the participation of seventy-four individuals.

The NCTF was organized under the auspices of the Center for Nanotechnology in Society at Arizona State University (CNS-ASU), which is funded by the National Science Foundation to perform research, training and outreach on the societal aspects of nanotechnology. The six sites participating in the NCTF, representing six distinct regions of the country, were:

- the University of New Hampshire (Durham), in the North East;
- Georgia Institute of Technology (Atlanta), in the South;
- the University of Wisconsin (Madison), in the Upper Midwest;
- the Colorado School of Mines (Golden), in the Mountain region;
- Arizona State University (Tempe), in the South West; and
- the University of California (Berkeley), on the West Coast.

The results of the study, therefore, are not limited to one section of the country, but reflect a truly national, informed, deliberative public assessment of NBIC potentials.

Each campus formed a facilitation team including a faculty leader and other assisting faculty and students. A complete list of facilitation team members can be found in

Appendix A. Dr. Patrick Hamlett (North Carolina State University, NCSU), coordinated the overall project, including the on-line components, and Dr. Michael Cobb (NCSU) oversaw the data gathering and analysis elements. Drs. Hamlett and Cobb both have experience in running the earlier CTFs and, under subcontract from CNS-ASU, coordinated many of the operational aspects of the NCTF as well.

Panelists. Each geographic site recruited its own panelists using newspaper and Internet advertising. While some sites attracted large numbers of volunteers and other sites attracted fewer – possibly due to the exotic and unfamiliar nature of the technologies in question – each site endeavored to create panels that were broadly representative of the communities from which they were drawn. Prospective panelists also answered a questionnaire to elicit demographic information and discover any possible conflicts of interest. Efforts at matching local and, in aggregate, national demographics were largely successful (see **Appendix B**), although both applicants and participants were somewhat more liberal and educated than the population as a whole. A small number of potential panelists were excluded for reasons of conflict.

Panelists were required to have Internet access in order to participate, although sites also arranged for the use of local libraries or other accessible venues if that became a hardship for participants. Because of the intensive nature of the NCTF and the considerable time commitment involved– two full weekends of face-to-face (F2F) meetings and 18 hours of Internet, or keyboard-to-keyboard (K2K) communication – organizers paid the participants $500 upon completion of their duties.

Background Materials. The organizers prepared a sixty-one page background document and delivered it to each panelist prior to the first F2F meeting. The document, describing the emergence of NBIC technologies and the debates about their anticipated social impacts, was drafted and edited by many researchers across CNS-ASU.

Following the Danish pattern, an Oversight Committee reviewed drafts of the document to help ensure that the materials were accurate, balanced, and accessible. The Oversight Committee consisted of Ida-Elisabeth Andersen, a project manager for the Danish Board of Technology in Copenhagen, and David Rejeski, the director of the Project on Emerging Nanotechnologies of the Woodrow Wilson International Center for Scholars in Washington, DC. The background document is available at http://www4.ncsu.edu/~pwhmds/.

Pre-and Post-tests. A pre- and post-test questionnaire was developed and administered to all panelists. The questionnaires assess several possible impacts of participation by the citizens, including factual learning and shifts in attitudes about NBIC technologies, as well as qualities of the deliberative process itself, including the presence and strength of cognitive and affective pathologies of deliberation and the level of consensus among the participants.

First F2F Weekend. During the first weekend of the NCTF, citizens gathered for face-to-face discussions that were led by facilitators from each of the campuses. The panelists discussed the background materials, the structure and goals of the project, and began to raise whatever concerns or issues they found significant. While the background document provided substantial information and framed the inquiry, the panelists had significant control over what specific issues or concerns should be addressed.

Internet Elements. The panelists from all six sites joined together for nine, two-hour synchronous online discussion sessions. During these Internet sessions, panelists from all the sites were exposed to the concerns, interests, values, and perspectives of panelists at all the other sites. During some of these sessions, content experts joined the discussions to respond to follow-on questions developed by the panelists and to fill in any gaps in the background materials. The content experts included technical specialists, a philosopher, and a specialist in regulatory processes. The content experts who participated were:

- Dr. Roberta M. Berry, the Georgia Institute of Technology (a specialist on the legal, ethical, and policy implications of life sciences research and biotechnologies);
- Dr. Steven Helms Tillery, Arizona State University (a specialist on cortical neuroprosthetics);
- Dr. Maxwell J. Mehlman, Case Western Reserve University (a specialist in the federal regulation of medical technology);
- Dr. Kristin Kulinowski, Rice University (Executive Director of the Center for Biological and Environmental Nanotechnology); and
- Dr. Jason Scott Robert, Arizona State University (a philosopher of science and the bioethicist).

Final F2F Weekend. The panelists gathered for a second and final F2F weekend during which they reconsidered the issues, problems, and concerns they had expressed during the first weekend in light of the additional information and discussions provided by the Internet sessions. Working with a facilitator, they then deliberated toward a set of policy recommendations that all panelists could endorse. The panelists themselves then compiled these recommendations into each site's Final Report.

Final Reports. After each panel reached a consensus among its members about what recommendations to advance, the panelists at each site wrote a Final Report representing that consensus. Each site's Final Report (available at http://www4.ncsu.edu/~pwhmds/final_reports.html) contains the specific recommendations that each panel endorsed, along with a discussion of issues, concerns, and values the panelists believe should be important in the management of NBIC technologies.

While the panelists at each site had been exposed to the concerns and issues panelists at the other sites thought were important, there was no effort to reach a single consensus involving all six sites; thus, each Final Report represents concerns and issues specific to that site. Nevertheless, when we compare the Final Reports, we find significant overlap among all six sites.

<u>Findings from the Reports</u>. An examination of the recommendations contained in the Final Reports illustrates the areas of concern expressed by panelists from all areas of the country about NBIC technologies of human enhancement.

- **Regulatory adequacy.** All sites (6 of 6) expressed significant concern about effective regulation of new NBIC technologies. Some sites recommended creating a new regulatory agency specifically charged with managing these technologies, while others recommended strengthening the Food and Drug Administration (FDA).
- **Public information.** All sites (six of six) strongly endorsed programs intended to keep the public informed about developments in human enhancement technologies, including conducting more deliberative panels and including discussions in high school and K-12 education.
- **Access & equity**. Nearly all the sites (5 of 6) included recommendations that emerging enhancement technologies be made available on an equitable basis to those who need them most.
- **Funding accountability**. Nearly all the sites (5 of 6) recommended that funding be prioritized for the treatment of disease before enhancements and that stakeholders should have a say in research decisions.
- **Safety**. Nearly all the sites (5 of 6) included recommendations for the careful monitoring of enhancement technologies, including the development of international safety standards for them.
- **Entrepreneurship & development**. Nearly all the sites (5 of 6) included recommendations that the development of these technologies should maximize their benefit, and that both public and private investment in these technologies is critical.
- **Ethical consideration.** A majority of the sites (4 of 6) recommended that ethicists and ethical considerations should be a formal part of decision-making about these technologies.
- **Privacy**. A majority of the sites (4 of 6) recommended that individual privacy be carefully protected in the development and deployment of enhancement technologies.
- **Health insurance**. A majority of the sites (4 of 6) were concerned about whether health insurance providers should be required to cover the costs of enhancements, and how health providers can provide adequate information about enhancements and other alternatives in health care.
- **Military uses**. Half of the sites (3 of 6) worried that NBIC enhancements might fall into the hands of terrorists or have other unanticipated military applications.
- **Environmental impacts**. Half of the sites (3 of 6) expressed concerns about possible environmental degradation from the use of NBIC technologies, especially in areas of waste management and toxicity.

- **Rights**. Half of the sites (3 of 6) wanted to ensure that individuals retain the right to refuse enhancements and that civil liberties and free choice be protected if and when these NBIC technologies are deployed.

Findings from the Pre- and Post-tests. Examination of responses to the pre- and post-tests provides statistically reliable data about the panelists' attitudes toward NBIC and human enhancement technologies. The data also provide insights into the quality of the deliberation in the NCTF.

- Deliberation resulted in reduced certainty among the participants about the benefits of enhancing human capabilities. Pre-deliberation, 82% were at least somewhat certain the benefits would exceed the risks; post-deliberation the percentage of these respondents dropped to 66%. Conversely, deliberation slightly strengthened participants' perception that most scientists were confident the benefits would exceed the risks (92% pre-deliberation and 96% post-deliberation).

- Despite concerns about risks, participants overwhelmingly favored government's guaranteeing access to human enhancements if they proved to be too costly for the average American. Prior to deliberation, 57% held that government should provide such guarantees; after deliberation, 63% said it should. On the other hand, deliberation resulted in a significant increase in the belief that individuals should have to pay out of pocket for most kinds of enhancement. Before deliberation, 74% thought insures should pay for most kinds of enhancements; after deliberation that percentage had shrunk to 55%.

- Deliberations increased general concern on the part of participants about NBIC developments but not at the expense of optimism. The percentage of those who expressed worries about NBIC technologies increased from 65% pre-deliberation to 80% post-deliberation, while the percentage of those who were not worried at all decreased from 35% pre-deliberation to 21% post-deliberation. Despite the shifts, the percentage of those who describe themselves as "hopeful" about NBIC technologies was 98% pre-deliberation and 98% post-deliberation.

- Deliberation increased specific worry about affording enhancements. Before deliberation, 63% were at least somewhat worried that the average family would not be able to afford enhancements; after deliberation, that percentage increased to 76%. Similarly, before deliberating, 48% of participants were at least somewhat worried that their own family would not be able to afford enhancements; after deliberating, that percentage increased to 60%.

- Despite increased concerns about costs, the panelists increased their support for individual responsibility for meeting the costs of enhancements. Those who believe that individuals, not insurance companies, should pay for enhancements shifted from 14% pre-deliberation to 32% post-deliberation.

Those who thought that we should avoid technologies that interfere with natural human development increased from 39% (29% strongly) pre-deliberation to 53% (41% strongly) post-deliberation.

- Deliberation reduced support for government spending for research on human enhancements. Before deliberating, participants' average score was 7.3 on an 11-point scale, where "11" meant they favored dramatically increased government spending and "1" meant dramatically decreased government spending. After deliberating, the average score fell to 6.3, which was the sharpest decline among five stimuli (health services, new energy sources, space exploration and weapons for defense). This finding is supported by another question that forced participants to decide between spending on enhancements versus space exploration; preference for spending on enhancements over space remained high, but it declined from 90% to 81%.

- Deliberation resulted in opposition to most kinds of hypothetical human enhancements that they were described in the Background Materials. Participants were asked to express their support or opposition to five kinds of enhancements on a five-point scale. After deliberating, participants opposed all enhancements except for "implants to catch diseases before they became dangerous". Before deliberating, participants also supported "bionic eyes" and were neutral about using nano-wires and implants to communicate with other people or computers. Respondents remained opposed to "administering drugs to prisoners to prevent escapes."

Some scholars who study small group deliberations – like those that go on in the NCTF – worry that such groups too easily fall prey to dynamics that can distort their results. Among these pathologies are what are known as "reputational cascades" and "social effects" which, they fear, induce members of deliberating groups to endorse statements of the group that, in fact, they reject personally. Thus, in order not to stand out from an apparent majority position, isolated individuals may agree to provisions that they actually object to. The pre- and post-test questionnaires attempted to assess the presence of such processes within the NCTF. The results strongly suggest that such pathologies were not present in these deliberations, and that panelists, in fact, deliberated.

- Given the highly speculative nature of the NBIC technologies, and the general lack of public knowledge about their development and implications, the panelists showed significant firming of opinions about them. Comparing pre-deliberation and post-deliberation results, the percentages who believed that the risks of NBIC technologies exceed the benefits increased from 6% to 28%, the percentage who believed that the risks equaled the benefits increased from 16% to 23%, and the percentage who thought that the benefits would exceed the risks also increased from 23% to 46%. Overall, the percentage pre-deliberation who had no opinion about the relative risks and benefits decreased from 55% to just 3% post-deliberation.

- The panelists showed significant increases in their substantive knowledge of nanotechnology and human enhancements. The pre- and post-tests assessed substantive learning by asking a set of factual questions and companion questions about the level of certainty of the panelists' answers to those factual questions. Deliberation increased panelists' knowledge on the factual question from an average of 4 correct responses of 6 to an average of 5.3 correct responses. When the panelists' level of certainty was included in the analysis – by having panelists say whether they were certain or were guessing and, e.g., rewarding correct and certain answers more highly than correct guesses – panelists' knowledge improved from 3.7 to 9.0 (on a scale from -6 to +12).

- The panelists demonstrated high levels of support for the specific provisions of each group's final report and high levels of congruence between their individual preferences and the contents of those reports. Overall, 89.9% of participants agreed or strongly agreed that their group's consensus report accurately reflected their individual preferences. Similarly, 81.2% said that they personally endorse almost every major point in their group's Final Report, while an additional 15.9% said that they personally objected to a few of the major points, and only 2.9% personally objected to many of the major points in the Final Report.

- The panelists' sense of internal efficacy – that is, their feeling of being competent to discuss issues like those raised in the deliberations as measured across several questions in the pre- and post-test – increased significantly. Similarly, their sense of trust – that is, their notion that other people will not attempt to take advantage of them – increased. However, their feelings of external efficacy – that is, their belief that their opinions or actions can actually affect political outcomes – decreased after the deliberations.

- The panelists found face-to-face deliberations to be significantly preferable to on-line only or to mixed formats. Those who preferred online communication shifted from 18% pre-deliberation to 3% post-deliberation. Those who favored face-to-face communication shifted from 33% pre-deliberation to 70% post-deliberation. And those who favored online and face-to-face communications equally shifted from 49% pre-deliberation to 27% post-deliberation.

CONCLUSIONS

We offer five conclusions from this national scale study.

First, average citizens very much want to be involved in the decisions that shape technologies that, in turn, shape their lives. Given good information, access to experts, and the time to discuss their concerns with other citizens, average people are able to learn the important details of even very complex issues, and to generate *thoughtful, informed, deliberative* recommendations. They also fully expect governmental and private sector decision-makers to listen to their ideas.

Second, although average people sometimes express reservations and concerns about new technologies, they remain strongly supportive of scientific and technical creativity and innovation. What they desire, however, is effective, trustworthy, and attentive monitoring of those new technologies. They believe that there have been too many episodes of highly touted new technologies that generated unexpected dangers for them to passively accept whatever technologies the market may generate.

Third, average citizens insist that they have continuous access to reliable, nonpartisan information about new technologies, and that they have frequent and repeated opportunities to express their concerns about how new technologies are managed.

Fourth, in addition to concerns about individual and environmental health and safety, average citizens express concern for a wider array of social risks that they think are important in the development of new technologies. For instance, issues of economics, equal access and equity are important, as are technological impact on personal freedom, civil rights, and political rights. Ordinary people have a fairly nuanced and sophisticated view of the role of new technologies in their everyday lives and in society at large.

Fifth, decision-makers in the government and in the private sector should pay careful attention to the concerns and issues expressed in this study. These panelists spent several weeks studying the issues involved in NBIC technologies, proposed trenchant questions to content experts, and engaged each other -- both in their local panels and with the panelists from across the country -- in clarifying, exploring, impressing political, cultural, moral, and economic values that they think will be affected by these technologies. These were thoughtful, committed, and well-informed panelists, not misinformed, hysterical, individuals being manipulated by outside groups.

SELECTED FURTHER READINGS

Berloznik, R.; Casert, R.; Enzing, C; van Lieshout, M; & Versleijen A. (2006) Technology Assessment on Converging Technologies: Literature Study and Vision Assessment [Background document for the STOA Workshop] Brussels: European Parliament.

Bostrom, N. (2003). Human Genetic Enhancements: A Transhumanist Perspective. Journal of Value Inquiry 37(4):493-506.

ETC Group. (2006). NanotechRX: Medical Applications of nano-Scale Technologies: What Impact on Marginalized Communities? (www.etcgroup.org).

Fukuyama, F. (2004). The World's Most Dangerous Idea: Transhumanism. Foreign Policy (Sept/Oct):42-43.

Lee, P. & Robra, M. (2005). Science, Faith and New Technologies: Transforming Life, Volume 1: Convergent Technologies. Geneva: World Council of Churches.

Nanotechnology Task Force. (2007). Nanotechnology: A Report of the US Food and Drug Administration. Washington, DC: US Government Printing Office.

President's Council on Bioethics. (2003). Beyond Therapy: Biotechnology and the Pursuit of Happiness. Washington DC: U.S. Government Printing Office.

Roco, M. & Bainbridge, W. (eds.). (2002). Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science. Arlington, VA: National Science Foundation and Department of Commerce report; published by Springer in 2003, http://wtec.org/ConvergingTechnologies/1/NBIC_report.pdf

Taylor, M.R. (2006). Regulating the Products of Nanotechnology: Does FDA Have the Tools it Needs? Project on Emerging Nanotechnologies. Washington, DC: Woodrow Wilson International Center.

Zonnefeld, L., Dijstelbloem, H. & Ringoir, D. (eds.). 2008. Reshaping the Human Condition: Exploring Human Enhancement. The Hague: Rathenau Institute, in collaboration with the British Embassy, Science and Innovation Network, and the Parliamentary Office of Science and Technology.

APPENDIX A: LIST OF FACILITATION TEAMS AT PARTICIPATING UNIVERSITIES

Arizona State University
David Guston, Professor of Political Science and Director, CNS-ASU
Cynthia Selin, Assistant Research Professor, CNS-ASU
Roxanne Wheelock, Graduate Assistant, CNS-ASU

Colorado School of Mines
Carl Mitcham, Professor, Director, Hennebach Program in the Humanities
Jennifer Schneider, Assistant Professor of Liberal Arts & International Studies

Georgia Institute of Technology
Susan Cozzens, Associate Dean of Research, Ivan Allen College
Ravtosh Bal, Graduate Assistant, School of Public Policy/Georgia State University

University of California, Berkeley
David Winickoff, Assistant Professor of Bioethics and Society
Mark Philbrick, Graduate Assistant, Department of Environment and Management
Javiera Barandiaran, Graduate Assistant, Goldman School of Public Policy

University of New Hampshire
Tom Kelly, Professor, Director, University Office of Sustainability
Elisabeth Farrell, Program Coordinator, Culture & Sustainability, Food, & Society Initiatives

University of Wisconsin, Madison
Daniel Kleinman, Professor of Rural Sociology
Jason Delborne, Post-doctoral Research Associate, Holz Center for Science and Technology Studies

APPENDIX B: SUMMARY DEMOGRAPHIC STATISTICS

	Applicant	Panelists	National
Sex	42% Male 58% Female	50% Male 50% Female	49% Male 51% Female
Education	25% some college 33% college degree 33% grad school	29% some college 31% college degree 31% grad school	50% some college or degree 9% grad school
Party ID	48% Democrat 11% Republican 30% Independent	44% Democrat 9% Republican 36% Independent	36% Democrat 27% Republican 37% Independent
Political Ideology	48% Liberal 14% Conservative 28% Moderate	41% Liberal 14% Conservative 27% Moderate	25% Liberal 36% Conservative 35% Moderate
Race	71% White 16% Black 5% Asian 5% Hispanic <1% Native Amer	65% White 15% Black 6% Asian 7% Hispanic 2% Native Amer	66% White 12% Black 4% Asian 15% Hispanic
Household Income	9% <$15K 16% >$15K <$35K 21% >$35K <$50K 23% .$50K <$75K 15% >$75K <$100K 16% >$199K	9% <$15K 21% >$15K <$$35K 16% >$35K <$50K 20% >$50K ,$75K 16% >$75K <$100K 17% >$100K	Median household income = $46K
Median Age	37 yrs old	39 yrs old	37 yrs old

APPENDIX C: FUTURE SCENES OF NANOTECHNOLOGY AND HUMAN ENHANCEMENT INCLUDED IN BACKGROUND MATERIALS

Included in the background material: "The following fictional scenes are extrapolations from current nanoscale research; they have been vetted for their technical plausibility by scientists currently working in nanoscale research. We hope these scenes will stimulate you to reflect upon the meanings, potentials and problems surrounding nanotechnology. The goal is to cultivate our collective ability to govern the implications of our technological ingenuity."[1]

Engineered Tissues

What are your thoughts on synthetically grown tissues and organs?
Using tissue printing technology, this system is able to build tissues with a vascular structure enabling the building of new organs.

Newly developed artificial tissues have been approved for use in wound healing as well as for skin grafts. These artificial tissues are made by "seeding" cells into a bioengineered scaffold where upon they reorganize it into a material suitable for use as an artificial tissue. In the process of tissue engineering the cell makes use of the scaffold components as nutrients. The starting scaffold is usually three dimensional Jello like material called a collagen gel. Made up mostly of water, sugars, and carbohydrates the gel also contains fibrous proteins like collagen, fibrin, and fibronectin which allow the cells to interact with the scaffold. The fibrous proteins are large and tend to form bundles of fibers, or fibrils. After some time the cells use up the scaffold materials reorganizing some of them into an artificial tissue that can then be used for surgical procedures.

Because the tissue is grown from the patients own cells there is almost never any rejection of the transplant. In some cases such as cancerous tissues this is not possible. However, using compatible cells from an appropriate donor gives a high success rate with no risk to the cell donor. Further developments of tissue engineers have made it possible to replace not only tissues, but also organs. One such technology is tissue printing which would allow one to produce whole organs from gel scaffolding and cells in an ingenious way.

This advanced technique allows for cells to be arranged within the scaffold in order to shape the tissue into larger structures. Cells are arranged by inserting them into a device analogous to an inkjet printer where cells are ink. The cells are then printed in a two dimensional pattern such as a circle. After a circle of cells is laid down on top of a sheet of scaffold, another layer of scaffold is placed on top, followed by yet another circle of cells and another sheet of scaffold. Several circles placed in this way will reorganize the scaffold to form a tubular tissue, thus creating a tissue with a vascular system. This is one of the biggest breakthroughs in tissue engineering, because it allows blood and nutrients to flow through the artificial tissue. Tissue printing thus allows us to develop microstructures. These developments have lead to externally grown tissues which can replace vital organs, as well as more general tissues like skin, bone, muscles, and arteries. The lack of transplant materials is no longer a problem.

[1] Technical background on the generation of the scenes may be found in C. Selin (forthcoming). "Negotiating Plausibility: Intervening in the Future of Nanotechnology." *Science and Engineering Ethics*.

Living with a Brain Chip

What are your thoughts on using cranial chips to enhance cognition?
This cranial chip features a data feed that puts information into the brain while the user is resting.

The next generation of cranial chip implants enables data transmission directly to the brain during rest without interfering with sleep. This data feed feature dramatically decreases the amount of time needed to assimilate new data each day, in fact the chipped person will just wake up knowing what was streamed into their head the previous night. The presence of the chip interferes with REM sleep, but the new data feed does not actually disrupt or alter in any way the sleep of the person with the implant.

The new disruptor cage is constructed out of more advanced materials that are lighter and more comfortable for the wearer. No longer is it necessary to lock head, neck and torso in to a rigid structure, the new generation of disruptor cages need only to lock to the head and upper vertebrae of the neck. This new format still provides the same protection against magnetic damage to the brain, advances in real time processing now allow for emergency shut off if the magnetic pulses are not directed exactly at the chip. The use of rare earth magnets in a wider net around the cranium makes for a more thorough disruption of the chip (even while undergoing data feed). This improves sleep by removing annoying dream sequences, restlessness, or need for sedatives previously common in past cranial chip implants.

These advances in cranial chip disruptors will work with all cranial chips. However, those with the newer (Gen. 3.4 or higher) cranial chips will see the most improvements and those who receive the soon to be released Gen. 4.0 will be able to take advantage of many new options. The 4.0 chips, like those before it, are a sandwich of carbon nanotubes, and gate molecules that are covered in neural growth promoters. The 4.0 chip features advances in neuron-to-chip interface, allowing for more neurons to contact the chip in more functional ways. This in turn increases the rate of information in and out of the chip, further increasing cognitive ability.

With this increase in connectivity of brain to chip and chip to brain comes increased assimilation and learning time. After implantation (still an outpatient procedure) it will take 30 to 90 days of neuron growth around the chip for it and the brain to become fully integrated. Upon chip integration, the newly chipped person will need to attend nine months of intensive classroom based courses, where they are taught new ways to think, process thoughts, and to categorize memories and data.

It is during this time, as the chip becomes enabled, that they will begin to feel the effects of the continuously running chip. As the brain becomes dependant on the chip the implantee will find it difficult to sleep. The first effects will be tossing and turning at night, followed by repetitive dreams, and finally inability to sleep. It is at this point that the cranial chip disruptor is needed and technicians will work with the chip implanted person (and spouse if necessary) insuring proper technique in fitting the disruptor, allowing the user to have the best nights sleep ever.

Automated Sewer Surveillance:

What are your thoughts on tracking individuals using their genetic material?
Ultra fast sequencing technology is used to analyze the DNA in harvested waste water, thus screening large populations.

Capitalizing on recent advances in very fast genome sequencing technologies, Sentinel Genetics is pleased to offer its new real-time in-stream wastewater sequencing system. Genetic material is randomly harvested from the waste-stream, usually at the sewage treatment facility. The automated system then prepares the DNA for sequencing and individual samples can be sequenced to the extent necessary to compare it to the National Registry in less than one second. A small bank of sequencers can process tens of thousands of samples each hour.

Sentinel Genetics developed the single strand sequencing technology, which works by quickly pulling strands of DNA through tiny nanoscale pores. Breakthroughs in micro and nanoscale mechanical devices that are small enough to automate preparations with the very small DNA strands have allowed for sequencing prices as low as pennies per thousands. Due to the large amount of non-human DNA that is in a wastewater stream, it was only through this high speed processing of samples at low price that large scale screening of municipal populations could become cost beneficial.

The database of America's genetic information has been available to law enforcement agencies since the inception of the United States Genomic Registry, but only in the last several years has it been complete enough to look for individuals. The Sentinel Genetics Sequencer data processing system is fully compatible with the Registry and provides advanced algorithms for comparing genomic and partial genomic material against the data in the Registry. By combining the massive throughput of the treatment-facility-based sequencer bank with portable units for signal triangulation through upstream testing, it is possible to track the location of individuals in metropolitan areas.

Disease Detector:

What are your thoughts on diagnosing disease before you are ill?
Doc in the Box is a device that tracks an individuals protein levels to monitor changes that imply early stage illness or disease before symptoms emerge.

BioMarker Detector created Doc in a Box with the ability to track a person's health status on a day-to-day basis from the comfort of their home. Doc in a Box is able to detect and record the health level of an individual by examining multiple proteins that are present in their blood, which are collected through a nearly-invisible needle causing no detectable pain. The proteins present in the blood will fluctuate, either up or down, as the body changes. These changes can be due to many different naturally occurring events such as puberty, pregnancy, or menopause, along with more unfortunate changes such as getting cancer, flu, or Alzheimer's disease. Doc in a Box is able to measure the amounts of specific proteins, or biomarkers, which are correlated to particular diseases, infections, or changes in the human body. These biomarkers are measured and recorded over time as health markers and tracked to develop a particular pattern specific for each individual called a biosignature. When there is a change in the body, there is an immediate change in the biomarkers outside the range of the biosigniture and detected by Doc in a Box.

Since the Doc in a Box is detecting markers on the molecular level, users will be informed of a cold or flu before a sore throat or cough ever occur. With the ability of Doc in the Box to detect diseases pre-symptomatically, people will be able to get treatment before they feel the illness and far before it is too late to treat the disease. For cancer patients, there will be biological implications of cancer before a tumor develops and before the cancer has time to spread. For Alzheimer's patients, early detection of biomarker changes will enable more effective treatment options, possibly before any memory loss.

Barless Prison:

What are your thoughts on a barless prison?
NanoCage has developed a caged drug that is injected into prisoners that becomes activated by radio control if prisons cross designated boundaries.

Ever since the first true nanomedicine product came on the market, a caged cancer drug that releases once bound to the cancer cell, researchers have been working towards utilizing these technologies for control purposes. This week it was announced that NanoCage, in collaboration with United Penitentiary Systems, have developed the first barless prison. Upon entry, inmates are injected with a cocktail of caged drugs that have a variety of effects when released via radio control. The base technology utilizes focused radio waves to target deep tissue tumors in places such as the abdominal cavity.

The basis for security is a net of radio transmitters that surrounds the facility. As a prisoner crosses the perimeter threshold, the radio signals will cause the release of one type of caged drug. For instance, if the prisoner crosses an inner 'warning' perimeter, a drug will be released that causes extreme vertigo and mild nausea. If the prisoner continues, the next perimeter will signal the release of incapacitating sedatives, and if the next signal is reached it will trigger a fatal dose of narcotics. These perimeters are spaced far apart enough to prevent unintentional crossing of more than the first.

The caged drug is connected to an antenna that upon receipt of a specific radio signal causes the physical break down of the carbon-nanotube-based cage. The package including the antenna is roughly half the size of a red blood cell. A coating of biocompatible molecules minimizes the physiological side effects from the caged drugs. There is, on very rare occasions, mild inflammatory responses that can be treated with over the counter anti-inflammatory drugs. Because some degradation of the caged drugs occurs naturally in the body, supplemental injections are advised every six weeks and always after drugs have been released.

Guards in barless facilities will be equipped with radio transmitters that can be aimed at individual inmates or larger areas to quell local unrest. The transmitters used by the guards will be unable to access the frequencies that trigger the fatal dosages.

NanoCage and United Penitentiary Systems claim this is the new model for working prisons, where inmate labor is unencumbered by restraints or monitoring devices and physical investment costs are not much more than traditional factories. The perimeter of these facilities need only be physically secured to keep people from trespassing on the grounds.

Bionic Eyes:

What are your thoughts on visual enhancement?
Opti-scan is an optical implant that looks and functions like a normal eye, yet has new enhancements enabling magnification, visualizing infra-red, and night vision.

Penetrode Inc. presents the Opti-scan visual enhancement system, the latest in ocular prosthetics. Opti-scan is capable not only of restoring sight to the blind but also of providing them with additional capabilities beyond those of the normally sighted. The housing of the implant is designed to mimic the external appearance of the eye and comes with an iris capable of changing colors to suit the daily tastes of our customers. A series of small motors implanted within the eye socket will provide human like eye movements while allowing for much greater tracking speeds than is possible with normal muscle.

The heart of the technology is thin film photosensitive ceramic panels that are located in the back of the eye. These panels take light signals and transduce them into electrical signals that stimulate the ganglial cells. The stimulated ganglial cells allow for the signal to be processed along the optical nerve to the visual cortex. If there is extensive damage to the ganglial cells or the optical nerve then the signal can be routed directly to the lateral genicuate nucleus, which is where the optic nerve connects to the visual cortex.

A massive zoom/magnification function will allow for telescopic sight similar to that of a high grade set of binoculars and the ability to greatly magnify nearby objects achieving magnification power similar to that of many laboratory microscopes. Opti-scan uses digital magnification features similar to those found in most digital cameras to achieve this additional functionality. Opti-scan is also available with night vision, thermal imaging, and high definition video and still photo capture. Images captured through the Opti-scan can be downloaded via Bluetooth and WiFi to any personal computing device. Depending upon the condition of your optic nerve, Opti-scan can be implanted through outpatient surgery and after a brief, two week course of training and therapy you and your new eyes will be fully functional.

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