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Policy Implications of Technologies for Cognitive Enhancement

Daniel Sarewitz and Thomas H. Karas

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Policy Implications of Technologies for Cognitive Enhancement

Daniel Sarewitz
Consortium for Science, Policy & Outcomes
Arizona State University
PO Box 874401
Tempe, AZ 85287-4401

Thomas H. Karas
Advanced Concepts Group
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-MS0839

Abstract

The Advanced Concepts Group at Sandia National Laboratory and the Consortium for Science, Policy and Outcomes at Arizona State University convened a workshop in May 2006 to explore the potential policy implications of technologies that might enhance human cognitive abilities. The group's deliberations sought to identify core values and concerns raised by the prospect of cognitive enhancement. The workshop focused on the policy implications of various prospective cognitive enhancements and on the technologies–nanotechnology, biotechnology, information technology, and cognitive science–that enable them. The prospect of rapidly emerging technological capabilities to enhance human cognition makes urgent a daunting array of questions, tensions, ambitions, and concerns. The workshop elicited dilemmas and concerns in ten overlapping areas: science and democracy; equity and justice; freedom and control; intergenerational issues; ethics and competition; individual and community rights; speed and deliberations; ethical uncertainty; humanness; and sociocultural risk.

We identified four different perspectives to encompass the diverse issues related to emergence of cognitive enhancement technologies:

- Laissez-faire – emphasizes freedom of individuals to seek and employ enhancement technologies based on their own judgment;
- Managed technological optimism – believes that while these technologies promise great benefits, such benefits cannot emerge without an active government role;
- Managed technological skepticism – views that the quality of life arises more out of society's institutions than its technologies; and
- Human Essentialism – starts with the notion of a human essence (whether God-given or evolutionary in origin) that should not be modified.

While the perspectives differ significantly about both human nature and the role of government, each encompasses a belief in the value of transparency and reliable information that can allow public discussion and decisions about cognitive enhancement. The practical question is how to foster productive discussions in a society whose attention is notably fragmented and priorities notably diverse. The question of what to talk about remains central, as each of the four perspectives is concerned about different things. Perhaps the key issue for initial clarification as a condition for productive democratic discussion has to do with the intended goals of cognitive enhancement, and the mechanisms for allowing productive deliberation about these goals.

ACKNOWLEDGMENTS

We would like to thank all the people who made the workshop on Policy Implications of Technologies for Cognitive Enhancement a success including the participants (see Appendix 2) who graciously shared their expertise and perspectives; the facilitators and note-takers (Appendix 2); and especially the workshop coordinators, Summer Jaromin at Sandia's Advanced Concepts Group and Nicole Heppner at the Consortium for Science, Policy and Outcomes at Arizona State University. We would also like to thank the Advanced Concepts Group and the V. Kann Rasmussen Foundation for funding this activity.

While we drew heavily on the ideas and concerns of the workshop participants, this final product is the responsibility of the two authors, Daniel Sarewitz and Thomas H. Karas.

Policy Implications of Technologies for Cognitive Enhancement

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I. Introduction

This report summarizes the findings of a workshop on policy approaches to the governance of human enhancement technologies, held at Arizona State University on May 3-5, 2006, and cosponsored by Sandia National Laboratories and ASU's Consortium for Science Policy and Outcomes. The idea for the workshop emerged from a conversation in the fall of 2005 among Gerry Yonas (Principal Scientist and Vice President, Sandia National Laboratories), James Canton (Chairman and CEO, Institute for Global Futures), and Braden Allenby (Professor of Civil and Environmental Engineering, Arizona State University). Allenby and Yonas had participated in a 2000, National Science Foundation-sponsored workshop on the societal implications of nanoscience and nanotechnology, and subsequently in a 2001 conference entitled, "Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science [NBIC]." Allenby had a long-standing interest in the societal implications of nanotechnology. All were aware that considerable work had been done on the ethical implications of human performance enhancement in general, and in the field of "neuroethics" in particular. Indeed, the prospect of a rapidly increasing technological capability to enhance human cognition has stimulated considerable activity in the U.S. and in Europe, including conferences, books, social science and humanities research, and even legislation.

This activity is perhaps surprising given the still-speculative nature of most of the technologies (and, therefore, of the social implications of those technologies). Nevertheless, such future-oriented discourse allows democratic societies to begin to prepare for the considerable challenges and opportunities that cognitive enhancement may create. Potentially, then, this speculative discourse offers an opportunity for anticipatory and adaptive governance of cognitive enhancement technologies, rather than yet another episode of after-the-fact response to more evolved technologies, which is typically characterized by divisive political debate and unsatisfactory regulatory regimes.

The workshop organizers thus decided to push discussions a step further and undertake an exploration of the potential *policy* implications of technologies that might enhance human cognitive capabilities. The group's deliberations sought to identify core values and concerns raised by the prospect of cognitive enhancement and to map out potential policy approaches. In particular, the workshop investigated how different political perspectives might give rise to alternative policy frameworks for the governance of enhancement technologies. The workshop thus aims at contributing to a foundation for public deliberation about the effective governance of technological capabilities that have the potential to transform society by transforming human cognition itself.

II. The Technologies

Nanotechnology, biotechnology, information technology, and cognitive science have been converging in several ways to enable cognitive enhancements. Nanotechnology is providing research instrumentation for improving knowledge of brain structure and function, as well as new means of drug delivery. Neurobiology is developing increased understanding of how brains and associated neural systems work. Information technology provides signal processing capabilities for neurobiological research and for interfaces among sensors, computers, brains, and prosthetic devices; it also enables modeling and simulation for computational neuroscience. Cognitive neuroscience has extended traditional cognitive psychology into the realm of understanding correlates between brain structure and function and cognition.

The workshop reported here focused on the policy implications of various prospective cognitive enhancements and on the technologies that might enable them, rather than on the details of the technologies themselves. Nevertheless, the workshop did review the technologies in order to establish a common baseline for discussion. Table 1 surveys the relevant technologies

Several caveats and comments about the table should be noted.

- Most items have a corresponding suggested literature reference in the footnotes. These references are meant to be illustrative, and by no means exhaustive.

- The list is roughly in order of least invasive to most. But the way in which any particular technology was applied could obviously change its degree of invasiveness compared with any other technology.

- The technologies are in various stages of research and development. Some might well never turn out to have real cognitive enhancement applications.

- Similarly, the listed cognitive enhancement applications depend on varying degrees of speculation and projection (e.g., insertion of a gene that apparently makes mice "smarter" in some tasks may or may not be the harbinger of a genetic modification that results in higher-IQ humans.)

III. Values, Concerns, and Goals Implicated by Cognitive Enhancement Technologies

The prospect of rapidly emerging technological capabilities to enhance human cognition makes urgent a daunting array of questions, tensions, ambitions, and concerns. Some of these issues can be traced to dilemmas that have occupied thoughtful humans for millennia, while others are new and unfamiliar. Humans are unique among animals largely owing to their powers of cognition, so it is reasonable, perhaps obligatory, that the promise of modifying such powers should stimulate deep reflection and wide discussion. Moreover, the diversity of perspectives, aspirations, capabilities and values that people bring to such reflections guarantees strongly divergent views on what ought to be done. The huge uncertainties attendant with the types of sociocultural change that enhancement technologies might stimulate in turn make it very difficult to connect any particular set of views and actions with any particular future outcomes.

To a considerable extent, then, the question at hand is not how best to achieve or avoid a particular version of a cognitively enhanced human future, but how to engage in a process of reflection and action that gives society and its institutions the best opportunities to thrive. This challenge must begin through a consideration of the values, concerns, goals, and perspectives ("values and goals," hereafter) implicated by technologies for cognitive enhancement. The workshop elicited dilemmas and concerns in ten overlapping areas.

Table 1: Cognitive Enhancement Technologies

Technology	Capabilities to be Enhanced
Teaching and Learning Techniques and Technologies (Environments, software)	Memory and Learning[1] Working memory[2] Knowledge and Decision-Making[3]
Computer Augmented Cognition Tools • "Human factors"-designed interfaces; surface electrodes for EEG Adaptive interfaces and systems • Augmented Reality	Memory (information storage and retrieval)[4] Knowledge (e.g. decision rules, context comprehension) storage and retrieval [5] Decision analysis (computation and simulation)[6] Perception (tailored sensory input, visualization)[7]

[1] K. Anders Ericsson, "Exceptional memorizers: made, not born" *Trends in Cognitive Sciences*, Vol. 7, No.6, June 2003 pp. 233-235, and E. Stern, "Pedagogy Meets Neuroscience, " *Science* Vol. 310, p. 745, 4 November 2005.

[2] See D.S Tan et. al., "The Infocockpit: Providing Location and Place to Aid Human Memory," *Workshop on Perceptive User Interfaces 2001, Orlando, Florida*, www.cs.cmu.edu/~desney/publications/PUI2001-Tan.pdf, accessed 22 August 2006, and G. Sinha, "Training the Brain," *Scientific American,* July 2005, p. 22-23.

[3] David Wood, "Army Uses Experimental Training to Bulk Up Brain Power," *Newhouse News Service* 2006, www.newhousenews.com/archive/wood020806.html, accessed 22 August 2006.

[4] See Dylan Schmorrow, ed., *Foundations of Augmented Cognition* (Mahwah, NJ: 2005: Lawrence Erlbaum Associates, Inc.)

[5] "Cognitive Agent that Learns and Organizes," SRI Artificial Intelligence Center (funded by DARPA Personalized Assistant that Learns program), at http://www.ai.sri.com/project/CALO, accessed 22 August 2006.

[6] DARPA Personalized Assistant that Learns program, at http://www.darpa.mil/ipto/programs/pal/index.htm, accessed 22 August 2006.

[7] See Steven K Feiner, "Augmented Reality: A New Way of Seeing," *Scientific American*, April 2002, Vol. 286, Issue 4, p. 50-58, and X. Fan et. al.. Extending the Recognition-Primed Decision Model to Support Human Agent Collaboration, *AAMAS'05*, July25-29, 2005, Utrecht, Netherlands, at st.psu.edu/yen/Lab/r-cast.pdf, accessed 22 August 2006.

Technology	Capabilities to be Enhanced
Transcranial Magnetic Stimulation	Analogic reasoning speed[8]
Psychopharmaceuticals	
• Cholinergic function enhancers	Learning, memory[9]
	Attention, psychomotor performance[10]
• Adrenergic agonists (e.g. guanfacine)	Working spatial memory[11]
• AMPA receptor modulators (e.g. Ampakines), CREB activators	Long-term memory[12]
• Caffeine, Modafinil	Attention[13]
Neural Interfaces	
• Peripheral nerve implants	Sensory perception[14]
• Vagus Nerve Stimulation	Recognition memory[15]

[8] B. Boroojerdi, "Enhancing analogic reasoning with rTMS over the left prefrontal cortex," *Neurology,* 2001, 56:526-528.

[9] K. J.Murphy, ,et. al." Chronic Exposure of Rats to Cognition Enhancing Drugs Produces a Neuroplastic Response Identical by Complex Environment Rearing," *Neuropsychopharmacology* (2006) 31, p. 90–100.

[10] M.S Mumenthaler et. al., "Psychoactive Drugs and Pilot Performance: A Comparison of Nicotine, Donepezil, and Alcohol Effects," *Neuropsychopharmacology* (2003) 28, p. 1366–1373.

[11] G. Lynch, "Memory enhancement: the search for mechanism-based drugs," *Nature Neuroscience Supplements*, 5, 2002, 1035-1038.

[12] S. Hall, "The Quest for a Smart Pill," *Scientific American*, September 2003, p. 54-65.

[13] Paul Root Wolpe, "Treatment, enhancement, and the ethics of neurotherapeutics," *Brain and Cognition* 50 (2002) p. 387–395.

[14] K.Warwick et. al.,"An attempt to extend human sensory capabilities by means of implant technology," *International Journal of Human Computer Inter*action, Vol. 17, 2004.

[15] K. B.Clark, "Enhanced recognition memory following vagus nerve stimulation in human subjects," *Nature Neuroscience* Vol. 2, no. 1, January 1999.

Technology	Capabilities to be Enhanced
• Cortical implants • Hippocampal implants	Sensory perception[16] Teleoperation of robotic (e.g.) sensor systems--telepresence[17] Computer interfaces[18] *(see "augmented cognition" above)* Memory[19]
<u>Genetic engineering</u> • Embryo choice • Germline modification	Psychometric measures of intelligence[20]

[16] L. Schwiebert et al. , "Biomedical Smart Sensor for Visually Impaired," *IEEE Sensors 2002*, Orlando FL., June 11-14, at http://citeseer.ist.psu.edu/cache/papers/cs/27136/http:zSzzSznewslab.cs.wayne.eduzSzbioSmartSensorVisuallyImpaired.pdf/schwiebert02biomedical.pdf, accessed 22 August 2006.

[17] M. Nicolelis, "Actions from Thoughts," *Nature*, Vol. 409, 18 January 2001, p. 403-407.

[18] Brower, V. When Mind Meets Machines. *EMBO reports*, . 6, no. 2, 2005, at http://www.nature.com/embor/journal/v6/n2/pdf/7400344.pdfm , accessed 22 August 2006.

[19] Theodore Berger et. al. Toward Replacement Parts for the Brain: Implantable Biomimetic Electronics as Neural Prostheses (Cambridge, MA: MIT Press, 2005).

[20] Y-P.Tang et. al., "Genetic enhancement of learning and memory in mice," *Nature*, 401, 2 September 1999, p. 63-6

1. Science and Democracy. The tension between ideals of scientific autonomy and demands of democratic decision making is nothing new, but emerges with particular poignancy and urgency in the debate over enhanced cognition. On the side of scientific autonomy, the end point of this tension is that society and politics should place no restrictions whatsoever on cognitive enhancement research. The end point on the side of democracy is that participatory decision making processes are the source of appropriate choices about the types of enhancement that should or should not be pursued.

The standard argument for scientific autonomy is at once philosophical and practical. More knowledge, more facts, and, indeed, more truth, are inherently liberating because they enable more effective action in the world. The deeper one's understanding of how the world works, the more effectively one can control one's surroundings. As scientific understanding penetrates the sources of cognition, it will increasingly enable the control—enhancement—of cognitive function. While scientific knowledge may of course be misused, its inherent value is positive, because it enables fact-based action that would not be possible without science. Moreover, because the detailed future paths of scientific and technological advance are unpredictable in detail, efforts to direct science along particular paths at the expense of scientific autonomy are inherently futile.

These arguments combine to form a strong political claim: that choices about what science to do and how to do it must be left largely to the scientists, and that efforts to slow or divert science from paths selected by scientists are usually misinformed and counterproductive. The a priori essence of these claims—deriving from the argument that human benefit is inherent in the progress of science—leads to the conclusion that opposition to research on human cognitive enhancement is rooted in irrational fears. Scientific autonomy must be protected, then, by insulating research from political interference, and by educating people so that they can escape from their irrationality.

Yet the force of arguments that support a scientific enterprise that is free to pursue cognitive enhancement without political fetters is countered by powerful arguments on behalf of democratic governance. Because cognitive enhancement could have profound effects on society and touch all citizens, all people have a potential interest in the consequences of cognitive enhancement. Therefore, everyone has a potentially legitimate voice in relevant decision-making processes. From this perspective, scientists are an important interest group, but in no way a uniquely privileged one. Moreover, because much cognitive enhancement research is supported by public monies, lines of political accountability run from science to the public.

The very unpredictability of consequences that is often invoked as a reason to protect scientific autonomy is an equally apt rationale in favor of stronger lines of democratic control: what advocates of cognitive enhancement research may portray as irrational fear can also be seen as differences in opinion about how an uncertain future might play out. Scientists and non-scientists, both, are ignorant about an uncertain future. Most scientific experts in cognitive enhancement are naturally going to focus on the potential benefits of the research because their own interests are advanced by the conduct of the research. Yet enthusiasm or hype voiced by experts for enhancement technologies that are at best speculative is no more or less inherently rational than fears based on speculation. Perhaps public discourse would benefit from a "Red Team" of technical experts whose job is to visualize problematic outcomes of the research, to create a level playing field for discussion about putative benefits and problems.

The ideals underlying the case for scientific autonomy are also in tension with the reality of democratic processes which, in fact, delegate decisions about distribution of scientific funds and organization of research to a wide range of agents, including elected officials, bureaucrats, and even the voting public. In other words, although the path of scientific advance may be unpredictable, in the real world it is nevertheless strongly influenced by choices made outside the laboratory.

There is no correct solution to the problem of balancing scientific autonomy and democratic accountability; the boundary will be continually negotiated and in constant flux. Because cognitive enhancement engages with the essence of human capabilities, it will appropriately remain a focus of democratic debate about the limits and prerogative of science for the foreseeable future.

2. Equity and Justice: Who will benefit from cognitive enhancement technologies? Presumably enhancements will be distributed largely through the marketplace; people will purchase desired capabilities. Will an uneven distribution of enhancements—which is presumably inevitable—exacerbate and more deeply entrench existing social stratification and patterns of inequity by providing cognitive advantage to those who already have socioeconomic and political advantage?

Will the enhanced discriminate against the unenhanced, thus further entrenching inequity? Will those who choose to remain unenhanced similarly be the subject of discrimination, or of de facto coercion to become enhanced in order to avoid such discrimination? Will popular demands arise for enhancement to become a public "entitlement," so as to level the playing field? If so, might enhancement ultimately enhance equity and justice by enabling those who are cognitively disadvantaged to compete more effectively in the world?

Alternatively, might an enhanced minority be discriminated against by a fearful or envious unenhanced majority?

3. Freedom and Control: How strong is the individual right to make decisions about enhancing one's own cognition? Society currently regulates "cognitive liberty" by controlling access to, and in some cases prohibiting access to, psychoactive drugs. How will such lines be drawn as the diversity and magnitude of enhancement capabilities continues to increase?

4. Intergenerational Issues: Specific challenges in the domain of freedom and justice are intergenerational, and can raise novel ethical quandaries. Do parents have proxy rights to decide how to enhance their children? If germ-line engineering becomes feasible, should today's humans have the right to determine the desired attributes of future generations? Conversely, if today's humans choose to restrict or reduce enhancement of future generations, are they unjustly interfering in a future generation's right to maximize its capabilities?

5. Ethics and Competition: Different nations may adopt very different approaches to governing science, as is currently on display with embryonic stem cell research. Some democratic nations (for example, those with strong egalitarian commitments) might decide that the ethical challenges raised by cognitive enhancement warrant strict regulation; others (for example, those who favor growth over equality) may be more permissive. Authoritarian regimes dedicated to enhanced economic or geopolitical competitiveness might forego controls altogether in order to pursue global advantage. Just as individuals might feel effectively coerced into participating in cognitive

enhancement to avoid discrimination, so might democratic nations decide, in the face of ethical compunctions, that they need to aggressively pursue enhancement technologies to maintain competitive position. The analogy with historical arms races is obvious.

6. Individual and Community Rights: Individual decisions to pursue desired outcomes (e.g., greater memory or intelligence) through cognitive enhancement, when made by many people, can lead to unintended or undesirable outcomes at the group or community level. (Traffic gridlock and air pollution are unintended and undesired outcomes of many people using automobiles to try to move quickly from one place to another.) No one knows what the outcomes of many people simultaneously pursuing enhanced intelligence, memory, or sensory acuity might be, but past experience suggests we should not expect that such enhancements at the individual level will automatically cumulate as enhancements of society as a whole, especially in the absence of simultaneous, political commitments to, say, equality and justice. Cognitive liberty, which is an individual right, is thus likely to be in tension with the rights of broader communities to pursue desired outcomes.

7. Speed and Deliberation: Rapid scientific advance is a de facto value underlying scientific research agendas. If cognitive enhancement is worth pursuing, then it is worth pursuing rapidly, and with bigger budgets. Those who see cognitive enhancement as a route to overcoming a variety of human imperfections, from medical disabilities to imperfect memory and the cognitive effects of aging, would also logically have an interest in seeing research on cognitive enhancement advance as rapidly as possible.

On the other hand, just as individual and community rights may be at odds, so may a commitment to speed be in tension with benefits that can arise from a slower advance of world-transforming technologies. Social institutions are often in a reactive mode when it comes to technology because the pace of technological change so often outstrips institutional response capabilities (rooted, as they are, in human decision processes). In particular, the types of trial-and-error or adaptive learning that may be necessary for wise governance of radical technological change is probably enhanced by slower, rather than faster, rates of innovation. The case for deliberation over cognitive enhancement may be particularly strong because the emerging technologies may have the capacity to alter the very human attributes around which most of society's institutions—political, cultural, even economic—have been organized.

8. Ethical Uncertainty: Most of the foregoing dilemmas are also subject to ethical uncertainty created by the unknown future directions, pace, and outcomes of cognitive enhancement itself. To some considerable extent, this uncertainty can best be addressed by seeking to contextualize ethical claims made about enhancement. For example, ethical arguments based on the individual should be contextualized by including collective ethical implications as well. This is difficult enough; yet while most considerations of the implications of new technologies might reasonably assume that core ethical principles acting in society are more-or-less stable, this need not be the case with cognitive enhancement, since we simply do not know how changing human cognitive attributes might, in turn, lead to significant changes in ethical norms. How, for example, might the rights attached to notions of identity and self evolve as the cognitive underpinnings of identity and self are modified through technological intervention?

9. Humanness. Beliefs and opinions about cognitive enhancement are related to notions of humanness. Emerging technologies for enhancement can be portrayed as part of a historical effort by humans to extend their ability to act in and on the world, employing everything from agriculture to eyeglasses to organized education. From this perspective, enhancing human capabilities is itself part of the essence of humanness—*I am, therefore I enhance*. Other perspectives emphasize core attributes of humanness that persist throughout such historical changes, for example, continuity in the nature of ethical discourse, or in the emotional and intellectual sources of life satisfaction. One's sense of where humanness resides therefore has an obvious connection to one's values and beliefs about cognitive enhancement.

10. Sociocultural Risk: Optimists and pessimists alike seem to see in cognitive enhancement a capacity for rapid sociocultural change due to changes in human intelligence and performance capabilities. Workshop participants sketched scenarios ranging, on the optimistic side, from a world where the poor and malnourished, through enhancement technologies, were brought up to cognitive speed with the affluent world, to, on the pessimistic side, a world in which people became increasingly addicted to recreational activities enabled by the hybridization of enhancement technologies and virtual reality simulations. Similarly, highest risk was attributed by some to actions that might slow the advance of cognitive enhancement technologies, and by others to the opposite—unchecked advance. The larger, unstated, agreement was that broad and perhaps radical sociocultural change—of whatever character—was likely to be an outcome of accelerating advances in cognitive enhancement capabilities. Such change has, in the past, always been destabilizing to some groups, and beneficial to others. Regardless of one's views about the promise or peril of cognitive enhancement, then, there should be little disagreement that it is likely to raise continual challenges for appropriate institutional response.

IV. Four Perspectives on Cognitive Enhancement, and their Policy Implications

We identified four different perspectives to encompass the diverse issues related to the emergence of cognitive enhancement technologies:

- Laissez-faire: In this view, the emphasis is on the freedom of individuals to seek and employ enhancement technologies based on their own judgment of potential benefit. The economic marketplace is therefore the appropriate mechanism for developing and distributing the technologies.
- Managed technological optimism: From this perspective, human enhancement technologies promise great benefits to individuals and to society, but such benefits cannot emerge without an active government role to promote innovation, ensure efficacy and fairness, and manage risk.
- Managed technological skepticism: According to this standpoint, quality of life arises more out of a society's institutions than its technologies. Markets are viewed as profit-maximizing, not quality-of-life maximizing. The role of government is to enable the more effective pursuit of social goals such as equity and justice, rather than to promote technological advance as a proxy for such goals.

- Human essentialism: This perspective starts with the notion of a human essence (whether God-given or evolutionary in origin) that should not be modified, either for religious reasons, or because it might destabilize both individual quality of life and social relations in unforeseeable ways. The role of government, then, is to restrict enhancement research and its application when it threatens essential human qualities.

Each of these perspectives encompasses a distinctive combination of values and desirable policy interventions that were investigated during the workshop.

1. Laissez-Faire

Values: Those with this perspective believe in the primacy of individual choice, mediated through the economic marketplace. Responsibility and accountability are primarily vested in the individual, not in the government. Research and innovation are viewed as powerful forces for human good because they are expressions of individual creativity, and because they expand the realm of choice available to individuals.

The marketplace is also seen as a powerful catalyst for innovation that, when combined with the potential of human enhancement technologies, could lead to the radical diversification of humanity—and consequent increase in freedom of choice and expression. Economic competition combined with cognitive enhancement competition should push human performance and capabilities to new heights. Economies of scale, and trickle-down of economic benefits, will help to ensure that benefits are not unacceptably concentrated among small groups. Transparency, in the form of easily available information about cognitive enhancement, will facilitate the efficiency and equity-serving behavior of the market.

Policies: Needless to say, appropriate policies for advancing this perspective should enable innovation and choice. One place where national government can play a positive role in is ensuring a level playing field for market competition, for example by monitoring the activities of other governments for inappropriate subsidies, and by ensuring that policy tools such as intellectual property (IP) are not used in the private sector as a way of blocking innovation. Governments may also need to protect the level playing field for consumers, so that the already-enhanced do not act, through non-market means, to protect their status by preventing others from becoming enhanced.

The government should also create a clearinghouse on product information (including testing and consumer complaints) so that consumers can understand what is known about efficacy, risks, and benefits of particular technologies. Companies, in turn, should be shielded from liability if they withdraw products from the market after problems have been uncovered. Regulation of particular technologies is not out of the question, but only if evidence of harm to humans or the environment becomes clear.

Some areas of tension exist within this policy framework. In particular, laissez-faire advocates may differ on how active the role of government ought to be in funding research, in helping to ensure the safety of new technologies, and in providing information to help consumers make wise choices. Interventions such as IP protection, liability limits, and regulation of childhood applications of cognitive enhancement also raise dilemmas about appropriate government action.

2. Managed Technological Optimism

Values: At the core of this perspective is the Enlightenment commitment to knowledge and innovation as key sources of human progress. Yet this value is tempered by the recognition and acceptance of a continual tension between a desire to maximize individual expression and technological innovation, and an understanding that the common good is not automatically served through individual action governed only by the marketplace. Similarly, while this view is optimistic about the capacity of enhancement technologies to improve society, it is aware of potential problems that could emerge, for example, through the commoditization of human cognitive attributes, and the commercial incentives that will arise to define attributes as deficient or sub-normal so as to justify the use of enhancement technologies. Nevertheless, this viewpoint embodies a tolerance toward risk, which is seen as an unavoidable aspect of technological society.

Thus, managed optimism is committed to a notion of balance between private and public action, although preferring to err toward the private because of a belief that people should have access to a diversity of opportunities created by enhancement technologies. Yet because there is no perfect balance point, and because the tensions inherent in this perspective are neither fixed, nor resolvable, there is also a commitment to continued surveillance, inclusive dialogue, education, and flexible policy approaches that can respond to unpredictable opportunities and challenges. The combination of technological optimism and commitment to pluralistic discourse creates its own tensions, however, because there is no guarantee that democratically expressed preferences will always be technologically optimistic. Indeed, in the U.S., political and economic elites, rather than broadly expressed public sentiment, have played the critical role in ensuring policy regimes that strongly encourage technological innovation.

Policy: The role of government embodies the tensions at the core of this perspective. Regulation is viewed as a blunt and ineffective instrument of governance because the pace of technological change is too fast to be usefully subjected to rigid regulatory regimes. Yet government can appropriately act to maximize innovation through the support of R&D, the design of more effective IP regimes, participation in international governance agreements, etc. Government also has a responsibility to foster the intelligence gathering and public discourse that can help inform democratic decision-making processes related to cognitive enhancement.

Crucially, however, from this perspective the governance of cognitive enhancement technology does not lie strictly in the domain of formal government policy-making but emerges from the interactions among governments, business, and NGOs, and the disseminated decision processes that emerge from such interactions. Because prescriptive policies are generally not sufficiently agile to deal with rapid technological change, this optimistic approach looks instead to a discourse of diverse voices and perspectives to be continually negotiating how society addresses the opportunities and challenges created by cognitive enhancement. Process—especially reflexive, democratic discourse— that is more important than any particular policy framework or prescription. Thus, as suggested already, one clear role for government is to ensure that discourse is inclusive, especially of groups that are typically marginalized in discussions about technological change.

3. Managed Technological Skepticism

Values: This perspective shares with the optimistic view the centrality of an Enlightenment commitment to truth and pluralistic, democratic discourse, and the recognition of a dynamic tension between individual and group motives and outcomes. Yet its differences from the optimistic position are not simply a matter of degree. The skeptical view is that technology is not inherently

beneficial. For example, it is not clear to the skeptics that enhancing IQ is necessarily a route to a better society; smarter people may or may not be wiser. Overall, techno-hype is viewed as ignoring the root causes of social problems. From this perspective, efficient paths to addressing social problems should focus on the institutional and policy frameworks within which technologies are deployed, rather than on technologies themselves. For example, reducing the number of people without health insurance is seen as a better route to improved human performance than pursuing cognitive enhancements. Skeptics prefer to err on the side of regulation and restraint in order to minimize risks and give institutions the space to understand, adapt to, and if necessary reject technologies based on democratic discourses.

Skeptics are therefore committed to a clear understanding of why technologies are being developed, what their likely (even if unpredictable) impacts are, and who is set to benefit from them in the short term and longer term, and who is not. (In this sense, the pessimists are more committed to the Enlightenment value of instrumental rationality than the optimists.) Such insights require a diversity of expert voices, so another commitment of the skeptical position is to a broader construction of what counts as legitimate expertise in discussions about technology. Sharing with the optimists the view that technological discourses are currently dominated by socio-political elites, skeptics in contrast believe that current decision processes are likely to preferentially benefit those elites and lead to undesirable commodification of cognitive attributes and amplified stratification of society.

Policies: While skeptics and optimists agree on the need to ensure that democratic discourse is linked to the governance of emerging enhancement technologies, skeptics are also more willing to entertain particular policy interventions. From this perspective, the potential for cognitive enhancement technologies to significantly transform society merits serious consideration of a range of policies, such as:

- A multi-year period of national public reflection and discussion on cognitive enhancement prior to making new or increased R&D commitments;
- Creation of a permanent program to research the social implications of cognitive enhancement;
- Creation of an independent analytical body, perhaps analogous to the former Office of Technology Assessment, to provide detailed, expert social impacts assessments of the full range of potential cognitive enhancement technologies;
- Reduced funding for cognitive enhancement research with direct military applications;
- Stronger regulation and oversight of human subjects research on cognitive enhancement;
- Stronger independent oversight of FDA phase II and III clinical trials; strengthening of phase IV postings on side effects;
- Requiring that applicants for federal funding of cognitive enhancement research include a) a serious analysis of potential risks and downsides; and b) an analytically grounded basis for any claims of social benefits; and
- Development of international governance agreements to prevent exploitation of developing countries or international cognitive stratification that could further impede development of poor countries.

4. Human Essentialism

Values: Notions of human dignity and a coherent, if not easily definable, human essence lie at the core of this perspective. Cognitive enhancement is therefore deeply problematic to the extent that it threatens either that dignity or that essence. Whereas the values motivating the three previous groups are all understood to reflect the contexts of modern, democratic societies, the claim of the essentialists is that their motivating values inhere in humanity itself, and are therefore more fundamental, and more deserving of protection. The other three perspectives also, to varying degree, look to the protection of individual rights as a source of democratic legitimacy, whereas essentialism looks to the protection of notions of the whole.

Essentialism draws from two different political and cultural traditions that are by no means easily reconcilable: cultural conservatives, especially in the U.S., and social liberals, particularly in Europe. God-given human nature lies at the core of the cultural conservative version of essentialism; culturally constructed human dignity is the social liberal version. Together, essentialism comprises five key dimensions:

- Species boundaries should not be violated; neither should the boundary between human and artificial be breached;
- Limits are a part of existence; accepting limits to human power and control is a virtue that honors reality;
- Humans are made in God's image (or, humans are a product of nature); modifying human nature thus violates God's (or nature's) design;
- The collective good—the family, the community—is a better measure of human welfare than individual autonomy. Thus, the efficient operation of the marketplace is not a proxy for human welfare; and
- Intangible and aesthetic values—beauty, appropriateness, repugnance ("yuk factor")—are valid reflections of essential human sensibilities and thus valid bases for critique of technologies.

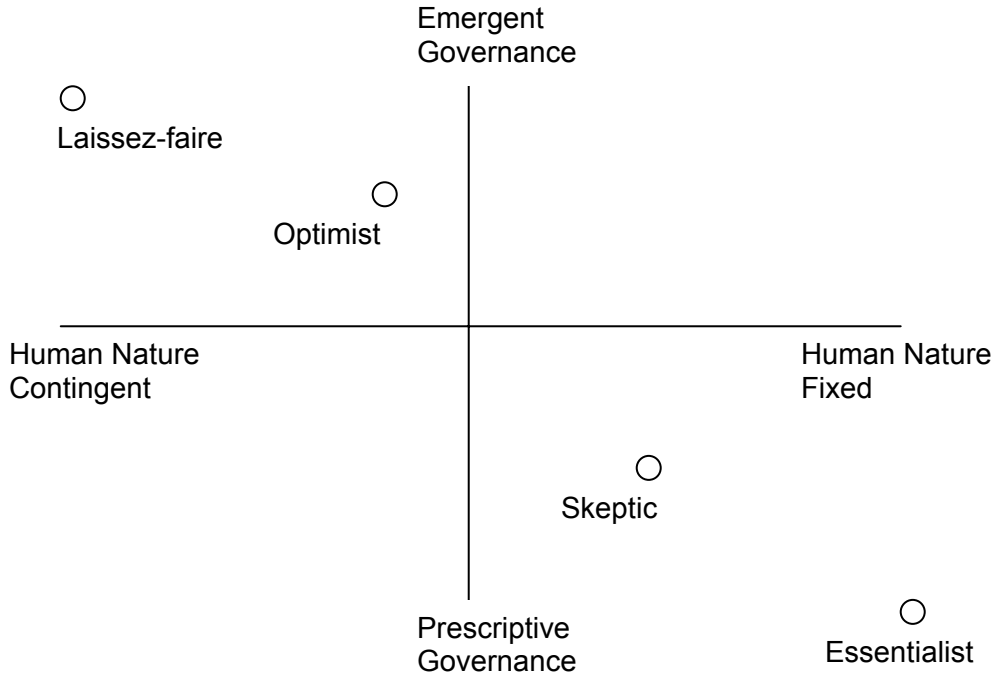
Policies: Protection of human dignity could be enshrined in the U.S. through a constitutional amendment, although this would present admittedly huge definitional challenges. Part of the essentialist policy agenda would be to develop a process that drew lines between appropriate and unacceptable enhancement technologies. Chimeras and cyborgs are both definitionally clear and should be banned. Prosthetic devices that were wired directly to the brain might not be acceptable; if they were used to enhance normal functioning (rather than restore sub-normal functioning) they would clearly be unacceptable. Overall, cognitive enhancement technologies used as therapy to the sick and disabled would be regulated more generously than those used to enhance normal function. Traditional risk-benefit frameworks for regulation would be inappropriate.

Other specific policies for discouraging inappropriate enhancement would include robust funding (including tax incentives) for public education on the risks of enhancement; a strong preference for research on nano- and info-technologies at the expense of biotechnologies; putting non-scientists with essentialist viewpoints on committees making decisions about funding for research on cognitive enhancement; prohibiting the recognition of IP for enhancement technologies in other countries; and an international agreement with like-minded nations to prohibit entry or emigration of enhanced citizens from other nations. Taxes and subsidies would be used to combat

any economic competitive advantage gained by countries that did practice cognitive enhancements deemed unacceptable from the essentialist perspective.

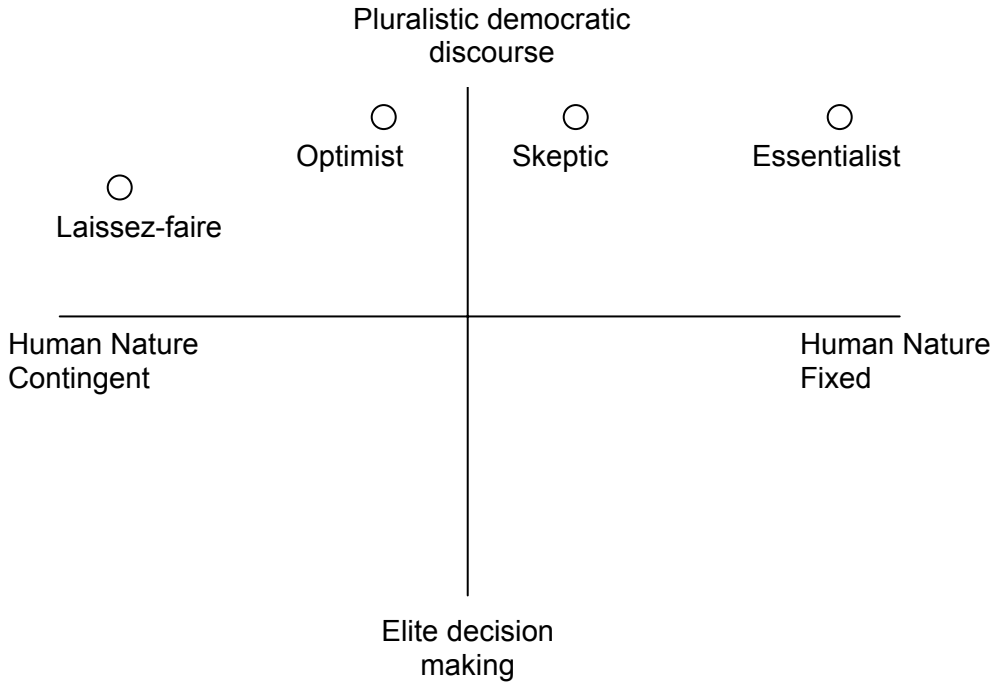
V. Option Spaces

A simplified, but perhaps still useful, way to think about how the four perspectives presented above relate to one another is shown on the graph below. The horizontal axis represents a spectrum of beliefs about the stability of human nature itself, ranging from humanness as a culturally and technologically contingent concept on the left, and notions of a fixed human essence on the right. The vertical axis represents the level of commitment to prescriptive intervention, with a weak commitment at the top, and strong at the bottom.



The value of this sort of graphic portrayal is purely qualitative; it offers some mild cognitive enhancement for conceptualizing how a variety of perspectives on technological cognitive enhancement relate to each other. One immediate conclusion to be drawn is that the philosophical and operational dispersion displayed by the four approaches cannot easily be reconciled. No apparent option space for policy intervention emerges.

There is, however, another dimension across which the four perspectives have some significant commonality. Each group professes a belief in the value of transparency and reliable information that can allow informed public discussion and decisions about cognitive enhancement—although the laissez-faire and essentialist positions tend to couch it as "education," and the optimists and skeptics term it "democratization." Of course, each perspective holds this belief in the confidence that the resulting discussions will favor its own goals. For example, on the laissez-faire end, that better information will allow the market to more efficiently advance the technologies; and on the essentialist end, that more public discussion will result in a moral convergence toward the essentialist view opposing cognitive enhancement.



Nevertheless, it seems to be a shared article of faith that more, and better informed, information flow and discussion is a good thing, and this creates a significant potential option space—an opportunity for action that can strengthen democratic process and clarify alternative paths for cognitive enhancement—perhaps opening up new paths and choices that allow for a better reconciliation of diverse perspectives.

Moreover, from a more disinterested, analytical perspective, the immense (if as yet ill-defined) opportunities and challenges offered by cognitive enhancement demand the engagement of as wide a variety of serious, informed perspectives as possible. It's not simply that the problem is too important to be left up to the experts, its that we have no idea what expertise is going to be relevant. The practical question, then, is how to foster productive discussions in a society whose attention is notably fragmented and priorities are notably diverse. A wide variety of existing mechanisms were mentioned at the workshop, from e-mail list-serves, chat-rooms and blogs to "science cafes," town meetings, and other face-to-face venues. One conclusion—represented by the workshop itself—is that the level of dispersed, democratic discourse surrounding cognitive enhancement is much more energetic and thoughtful, at a much earlier stage of technological development, than has been the case for other contended technologies in the past. All four perspectives would likely see this as a good thing (although the Laissez-faire group would be less supportive than the other three).

Yet the question of what to talk about remains central. To some considerable extent, the four perspectives summarized above are talking, and worried, about different things. The laissez-faire perspective is most concerned with protecting personal autonomy and market efficiency; the optimistic, with maximizing technological advance; the skeptical, with improving social policies; and the essentialist, with maintaining a core set of values. The ways in which cognitive enhancement technologies might intersect with each of these perspectives is far from clear. Thus, perhaps the key issue for initial clarification as a condition for productive democratic discussion has to do with the intended goals of cognitive enhancement. What are scientists trying to accomplish? On what bases

are public and private funding for research being justified? Who (institutionally) is funding the research, and who is conducting it? How quickly, and in what directions is the science moving? What sorts of technical scenarios are plausible, and what sorts are unlikely? The point here is to ground discussion in a concrete, shared (although perhaps rapidly evolving) baseline that can enhance productive and civil group deliberation in what is likely to be a fractious but essential arena of human endeavor over the foreseeable future.

Indeed, theories, methods and protocols for combining pluralistic democratic discourse with complex processes of technological innovation have been proposed from a number of academic perspectives (see "For Further Reading," below), and are actually now being tested in the field of nanotechnology, for example with the NanoNed program at the University of Twente in the Netherlands (http://www.nanoandsociety.com/projects/nanoned.htm), and at the Center for Nanotechnology in Society at Arizona State University in the U.S. (http://www.cns.asu.edu). Approaches such as Constructive Technology Assessment and Real-Time Technology Assessment treat technological innovation as a socially embedded process that is always subject to human deliberative decisions, rather than as an isolated activity to which society can only respond after-the-fact. These approaches aim to build adaptive and iterative governance capabilities into the innovation process itself. While still in their relative infancy, they may offer a framework for encountering the diversity of political perspectives, and complexity of innovation processes and outcomes, presented by the emerging technological capacity for human cognitive enhancement.

Appendix 1: For Further Reading

Converging Technologies

Mihail C. Roco and Carlo D. Montemagno, eds., *The Coevolution of Human Potential and Converging Technologies*, (Annals of the New York Academy of Science, Vol. 1013, May 8, 2004).

Bioethics and General Enhancement

Martha J. Farah, "Neuroethics: the practical and the philosophical," *TRENDS in Cognitive Sciences,* Vol. 9, No.1, January 2005, p. 34-40.

Carl Elliott and Peter D. Kramer**,** *Better Than Well: American Medicine Meets the American Dream* (New York: W.W. Norton, 2004).

Francis Fukuyama, *Our Posthuman Future: Consequences of the Biotechnology Revolution* (New York: Farrar, Straus, and Giroux, 2002).

Joel Garreau, Radical *Evolution: The Promise and Peril of Enhancing Our Minds, Our Bodies -- and What It Means to Be Human* (New York: Doubleday, 2005).

James Hughes, *Citizen Cyborg: Why Democratic Societies Must Respond to the Redesigned Human of the Future* (Boulder, CO: Westview Press, 2004).

Leon Kass et. al., *Beyond Therapy: Biotechnology and the Pursuit of Happiness* (Washington, D. C.: President' s Council On Bioethics, October 2003), available at http://www.bioethics.gov/reports/beyondtherapy/.

Erik Parens ed. *Enhancing Human Traits: Ethical and Social Implications* (Washington, D. C. Georgetown University Press, 2000).

Charles T. Rubin, "The Rhetoric of Extinction," *The New Atlantis*, Winter 2006, p. 64-73.

Gregory Stock, *Redesigning Humans: Our Inevitable Genetic Future,* (Boston: Houghton Mifflin, 2002).

World Transhumanist Association, at http://www.transhumanism.org/index.php/WTA/index/.

Neuroethics and Cognitive Enhancement

Martha J. Farah et. al., "Neurocognitive enhancement: what can we do and what should we do?" *Nature Reviews: Neuroscience*, Vol. 5, May 2004, p. 421-425.

Arthur L. Kaplan, "Is Better Best? A noted ethicist argues in favor of brain enhancement," *Scientific American*, September 2003, p. 104-105.

"Transhumanist Resources: Intelligence Amplification," web page at http://www.aleph.se/Trans/Individual/Intelligence/index.html.

Paul Root Wolpe, "Neurotechnology and Brain-Computer Interfaces: Ethical And Social Implications," in *Emerging Technologies and Ethical Issues in Engineering: Papers from a Workshop, October 14-15, 2003*, available at http://www.nap.edu/catalog/11083.html.

Governance of Complex Emerging Technologies

David Guston and Daniel Sarewitz, Real-Time Technology Assessment. *Technology in Culture* 24, 93-109, 2002.

A. Rip T. Misa and J. Schot, ed., Managing Technology in Society. The Approach of Constructive Technology Assessment (Pinter Publishers, London and New York, 1995).

M. Schwarz and M. Thompson *Divided We Stand.* (Philadelphia: University of Pennsylvania Press, 1990).

J. Wilsdon, and R. Willis, *See-Through Science: Why Public Engagement Needs to Move Upstream.* (London: Demos, 2004).

Appendix 2: Workshop Participants

Workshop on the Policy Implications of Cognitive Enhancement Technologies

Arizona State University
3-5 May, 2006

PARTICIPANTS

BRADEN R. ALLENBY is Professor of Civil and Environmental Engineering, and of Law, at Arizona State University, having moved from his previous position as the Environment, Health and Safety Vice President for AT&T in 2004. Dr. Allenby received his BA from Yale University in 1972, his JD from the University of Virginia Law School in 1978, his Masters in Economics from the University of Virginia in 1979, his Masters in Environmental Sciences from Rutgers University in the Spring of 1989, and his PhD in Environmental Sciences from Rutgers in 1992. He is President of the International Society for Industrial Ecology; Chair of the AAAS Committee on Science, Engineering, and Public Policy; a Batten Fellow in Residence at the University of Virginia's Darden Graduate School of Business Administration; and a Fellow of the Royal Society for the Arts, Manufactures & Commerce. From 1995 to 1997, he was Director for Energy and Environmental Systems at Lawrence Livermore National Laboratory, and from 1991 to 1992 he was the J. Herbert Holloman Fellow at the National Academy of Engineering in Washington, DC. His areas of expertise include design for environment, industrial ecology, telework and netcentric organizations, and earth systems engineering and management..

THEODORE W. BERGER is the David Packard Professor of Engineering, Professor of Biomedical Engineering and Neuroscience, and Director of the Center for Neural Engineering at the University of Southern California. Dr. Berger received his PhD from Harvard University in 1976; his thesis work received the James McKeen Cattell Award from the New York Academy of Sciences. He conducted postdoctoral research at the University of California, Irvine from 1977-1978, and was an Alfred P. Sloan Foundation Fellow at The Salk Institute from 1978-1979. He joined the Departments of Neuroscience and Psychiatry at the University of Pittsburgh in 1979, being promoted through to Full Professor in 1987. Since 1992, he has been Professor of Biomedical Engineering and Neurobiology at the University of Southern California. During his career he has received numerous awards and honors: McKnight Foundation Scholar Award, NIMH Research Scientist Development Award (twice), Fellow of the AAAS, NIMH Senior Scientist Award, Lockheed Senior Research Award, Fellow of the American Institute for Medical and Biological Engineering, Person of the Year "Impact Award" by the AARP in 2004 for his work on neural prostheses, National Academy of Sciences International Scientist Lecturer , IEEE Distinguished Lecture, Senior Member of the IEEE, "Great Minds, Great Ideas" award from the EE Times, and USC's Associates Award for Creativity in Research and Scholarship. He has published over 170 journal articles and book chapters, and is the co-editor *Toward Replacement Parts for the Brain: Implantable Biomimetic Electronics as Neural Prostheses* (MIT Press, 2005). His research interests are in (i) the development of biologically realistic, experimentally-based, mathematical models of higher brain (hippocampus) function, (ii) application of biologically realistic neural network models to real-world signal processing problems, (iii) VLSI-based implementations of biologically realistic models of higher brain function, (iv) neuron-silicon interfaces for bi-directional communication between brain and VLSI systems, and (v) next-generation brain-implantable, biomimetic signal processing devices for neural prosthetic replacement and/or enhancement of brain function.

EVA CALDERA is the Associate Director of the Institute for Ethics and Research Professor of Law at the University of New Mexico School of Law. Her teaching and research interests include bioethics, neuroethics, ethics and technology, and ethics education. She has recently worked with Sandia National Laboratories in analyzing ethical issues related to cognitive systems design. She also serves as a member of the Human Research Review Committee at the UNM Health Sciences Center. Before coming to UNM, she spent eight years in private law practice representing clients in a variety of matters involving litigation, labor, insurance, the environment, education and other issues. Both her law degree and her undergraduate degree in philosophy are from Harvard University.

NIGEL M. de S. CAMERON is Associate Dean and Research Professor of Bioethics at Chicago-Kent College of Law, President of the Institute on Biotechnology and the Human Future, and Director of the Center on Nanotechnology and Society—all within Illinois Institute of Technology. His articles on nanotechnology and its potential impacts on the human condition include a commissioned paper in a forthcoming National Science Foundation volume on the technology's societal implications, and he is currently editing a book on the topic. Cameron also serves on

the advisory boards of *Nanotechnology Law & Business* and the Converging Technologies Bar Association, and he was a co-chair of the 2005 International Congress of Nanotechnology. In addition, the media frequently call upon Cameron as a nationally recognized commentator on technology and human dignity. Cameron has studied at Cambridge University, the University of Edinburgh, and Edinburgh Business School.

JOHN C. CUMMINGS, workshop team member, is a senior manager in the Advanced Concepts Group (ACG) at Sandia National Laboratories in Albuquerque, NM. In June 2005, he returned to Sandia after three years in Washington, DC, as the Director of the R&D program for critical infrastructure protection for the Science and Technology Directorate of the Department of Homeland Security (this followed an assignment with the White House Homeland Security Transition Planning Office). Before his position with DHS, he was the Deputy to the Chief Technology Officer at Sandia National Laboratories. He has worked at Sandia for 30 years serving in a wide variety of technical staff and management positions. His technical work includes research in experimental fluid mechanics, combustion, and the use of laser-based instrumentation. Before coming to Sandia, he was employed by the Engineering Sciences Department at TRW Systems, Inc., where he conducted studies of HF and DF chemical lasers. He is a member of the American Physical Society Division of Fluid Dynamics, and he served as the U.S. representative to the International Atomic Energy Agency working on the mitigation of hydrogen combustion hazards in nuclear power plants. He received his BS, MS, and PhD (1973) degrees from Caltech. His PhD research involved the development of a cryogenic shock tube and the study of strong shock waves in gaseous and liquid helium. He is the author or coauthor of over 50 technical publications and reports.

MARTHA FARAH grew up in New York City and went to college at MIT, where she earned undergraduate degrees in Metallurgy and Philosophy in 1977. She studied Experimental Psychology at Harvard, earning a PhD in 1983 and going on to postdoctoral studies in Neuropsychology at MIT and the Boston VA Hospital. She has taught at Carnegie Mellon University and the University of Pennsylvania, where she is now Professor of Psychology and Director of the Center for Cognitive Neuroscience. Professor Farah's work spans many topics within cognitive neuroscience, including visual perception, attention, mental imagery, semantic memory, reading, prefrontal function, and most recently, neuroethics. Her publications include: *Visual Agnosia,* (MIT Press, 1990; 2nd edition, 2004), *The Cognitive Neuroscience of Vision* (Blackwell, 2000), and the edited volume: *Patient-based Approaches to Cognitive Neuroscience* (MIT Press, 1999; 2nd edition 2006), and she is the *Journal of Cognitive Neuroscience* Associate Editor for Neuroethics. She is a recipient of the American Psychological Association's Early Career Contribution Award, the National Academy of Science's Troland Award, and a Guggenheim Fellowship. She currently lives in Philadelphia with her 10 year-old daughter and a Tibetan Terrier of unknown age.

MARK S. FRANKEL, PhD, is director of the Scientific Freedom, Responsibility and Law Program at the American Association for the advancement of Science (AAAS), where he develops and manages the Association's activities related to science, ethics, and law. He has conducted Congressional seminars on the social and policy implications of the Human Genome Project, directed a study on human inheritable genetic modifications, and is organizing a meeting in June 2006 on human enhancement. Dr. Frankel is a Fellow of AAAS.

MICHAEL E. GORMAN is a Professor in the Department of Science, Technology & Society at the University of Virginia, where he teaches courses on ethics, invention, discovery and communication. His research interests include experimental simulations of science, described in his book *Simulating Science* (Indiana University Press, 1992) and ethics, invention and discovery, described in his book *Transforming Nature* (Kluwer Academic Press, 1998). With support from the National Science Foundation, he has created a graduate concentration in Systems Engineering in which students create case-studies involving ethical and policy issues; these studies are described in Gorman, M.E., M.M. Mehalik, and P.H. Werhane, *Ethical and environmental challenges to engineering* (2000, Englewood Cliffs, NJ: Prentice-Hall). He has also edited a volume on *Scientific and Technological Thinking* (Lawrence Erlbaum Associates, 2005). He taught the first course on Earth Systems Engineering and Management. His current research is in the kind of interdisciplinary trading zones that will be needed to achieve true technological progress, especially in the environmental area.

DAVID H. GUSTON is Professor of Political Science and associate director of the Consortium for Science, Policy and Outcomes at Arizona State University. He is also director of the Center for Nanotechnology in Society (CNS-ASU), an NSF-designated Nano-scale Science and Engineering Center. CNS-ASU is beginning the first year of its 5-year, $6.2 M grant from NSF to explore the societal implications of nanotechnologies. His book, *Between Politics and Science: Assuring the Integrity and Productivity of Research* (Cambridge U. Press, 2000), won the 2002 Don K. Price Prize from the American Political Science Association for best book in science and technology policy. Professor Guston is the North American editor of the peer-reviewed journal *Science and Public Policy*, and he is co-vice-chair of the 2006 Gordon Research

Conference on Science and Technology Policy. In 2002, he was elected a fellow of the American Association for the Advancement of Science (AAAS), and he is the immediate past chair of the AAAS Section on Societal Impacts of Science and Engineering. He holds a BA from Yale and a PhD from MIT, and he performed post-doctoral training at the Belfer Center for Science and International Affairs at Harvard University's Kennedy School of Government.

RICHARD J. HAIER received a PhD in Psychology from the Johns Hopkins University in 1975. He was a Staff Fellow at the National Institute of Mental Health from 1976-1980 (Laboratory of Psychology and Psychopathology) and on the faculty of Brown University School of Medicine (Department of Psychiatry and Human Behavior) from 1980-1985. Currently, Dr. Haier is Professor of Psychology at the University of California, Irvine (School of Medicine). Dr. Haier has used brain imaging with PET and MRI for the last 20 years to study individual differences in personality and intelligence. He has reported a series of PET studies that suggest brain efficiency may be related to intelligence and learning . Recently, he has shown that subjects with high intelligence scores show increased brain activity in posterior information processing brain areas when they are engaged in a passive task with no problem solving or reasoning . His newest research with MRI and voxel-based-morphometry has identified specific brain areas where gray and white matter volumes correlate to intelligence; these areas are distributed throughout the brain and differ for young and older adults, as well as for men and women. His most speculative work uses brain imaging to study the effects of anesthetic drugs; results suggest a neurobiological basis for consciousness and a possible link to the neurobiological basis of intelligence.

JAMES HUGHES teaches Health Policy at Trinity College in Hartford Connecticut, and serves as Trinity's Associate Director of Institutional Research and Planning. He also serves as the Executive Director of the Institute for Ethics and Emerging Technologies and its affiliated World Transhumanist Association. Dr. Hughes produces the weekly syndicated public affairs talk show *Changesurfer Radio*, writes the Change Surfing column for Betterhumans.com, and contributes to the democratic transhumanist *Cyborg Democracy* blog. He is the author of *Citizen Cyborg: Why Democratic Societies Must Respond to the Redesigned Human of the Future*. He lives in rural eastern Connecticut with his wife, the artist Monica Bock, and their two children.

WENDELL JONES, workshop team member, is currently interested in the performance of human systems and human/machine systems. His work in the ACG represents the melding of two major components of his professional career. He joined Sandia in 1976 after completing MS and PhD degrees at the University of Washington in materials science. In the metallurgy research organization at Sandia, he worked as a staff member and supervisor in physical, mechanical, and corrosion metallurgy. In collaboration with others, he worked to develop physical mechanism-based constitutive models that could predict the structural response of alloys in high temperature applications. The sensitivity of this particular kind of non-linear deformation to history/starting condition and the co-evolution of microstructure and mechanical state makes this modeling particularly daunting. In 1992, the Lab's President created the Ombuds Program at Sandia and, after a selection process, asked him to establish this program for Sandia at the New Mexico site. He spent the following 11 years working in crisis intervention and mediation as an ombudsman. During this time, he continued to develop expertise and experience in human formation, psychology, sociology, ethics, system dynamics, and dispute resolution. This work provided a rich experience in how human systems really work. In seeking to understand a theoretical basis for the things he was seeing, he developed expertise in the application of complex adaptive theory to human systems. This growing interest in understanding how humans and systems of humans form, evolve, and dissolve spawned an intersection with the Advanced Concepts Group in 2002. This intersection increased, and he began work at the ACG in 2003. The connecting point between his materials science research and his work on human systems is in the challenge of modeling non-linear, co-evolving systems. He is working to support Sandia's evolution into becoming a laboratory that fully considers humans (individually and collectively) to be part of the technology oriented systems that we study.

TOM KARAS, the workshop coordinator, has been at Sandia National Labs since 1996, and with the ACG since its beginning in 1999. Major topics he has worked on include a survey of "futurology," bioterrorism (emphasizing public health surveillance), the aging of the population, approaches to the war on terrorism, and border security, energy policy, and, most recently the organization of this workshop. Before joining the ACG, he worked in a Sandia systems analysis center. His first project there was a study of Sandia R&D in the context of U.S. national R&D policy. He then shifted into the Arms Control Studies department where he did studies on nuclear-test-ban-related issues, deterrence, START issues, and the concept of "de-alerting" strategic forces. He also managed a contract with some well-placed Muscovites for a study on "strategic stability." Previously, he spent 13 years with the U.S. Congress's Office of Technology Assessment (shut down at the end of '95), where he directed or participated in projects that included one on civilian space policy, two on anti-satellite weapons and ballistic missile defenses (spanning four years), one on arms control verification, one on the proliferation of weapons of mass destruction, and, finally (and incompletely) one on countering

proliferation of weapons of mass destruction. Before OTA, he wrote a book on the military uses of space, worked for a nonprofit research group in Washington, and taught political science for Boston University in Europe and Boston. His degrees in political science are from Yale (BA) and Harvard (PhD).

ADAM KEIPER is a fellow at the Ethics and Public Policy Center, a think tank in Washington, D.C., and the co-director of its program on Science, Technology, and Society. He is also managing editor of *The New Atlantis*, a quarterly journal with a focus on the social, political, and ethical implications of advances in science and technology. He writes and lectures on subjects ranging from space policy to nanotechnology to the "politicization of science." He has worked on Capitol Hill, in various think tanks, and in a corporate lobbying office.

ZACK LYNCH is an economic and social forecaster advising global organizations on the impact of neurotechnology on business, government, and society. He is the publisher of the investment newsletter, Neurotech Insights, editor of Brain Waves, an industry weblog providing commentary on the intersection of neuroscience and society, and co-author of NeuroInsights' annual report on The Neurotechnology Industry: A Strategic Investment and Market Analysis Guide for the Global Neurological Disease and Psychiatric Illness Markets. Mr. Lynch serves on the advisory boards of the McGovern Institute for Brain Research at MIT, Center for Neuroeconomic Studies, Center for Cognitive Liberty & Ethics and Socialtext, a software company. Previously, he was an executive and founder of several enterprise software companies in profit optimization and collaborative forecasting. He received an MA in Economic Geography and double BS in Evolutionary Biology and Environmental Science, all from UCLA.

GARY MARCHANT is a Professor of Law and Professor of Life Sciences at Arizona State University, and is the Lincoln Professor of Emerging Technologies, Law and Ethics at ASU. He is also the Executive Director of the Center for the Study of Law, Science and Technology at ASU law school. Professor Marchant has a PhD in Genetics from the University of British Columbia, a Masters of Public Policy degree from the Kennedy School of Government , and a law degree from Harvard. Prior to joining the ASU faculty in 1999, he was a partner in a Washington, D.C. law firm where his practice focused on environmental and administrative law. He teaches and researches in the subject areas of environmental law, risk assessment and risk management, genetics and the law, biotechnology law, food and drug law, legal aspects of nanotechnology, and law, science and technology.

EVAN MICHELSON is a research associate for the Project on Emerging Nanotechnologies at the Woodrow Wilson Center for International Scholars. Mr. Michelson received a MA in international science and technology policy from The Elliott School of International Affairs at The George Washington University, a MA in philosophical foundations of physics from Columbia University, and a BA in philosophy of science from Brown University. He previously served as a visiting researcher in the Korea Science and Engineering Foundation's Performance Assessment Team as part of the National Science Foundation's Korea Summer Institute program. In 2004, he developed public outreach and education programs as a Christine Mirzayan Science and Technology Policy Graduate Fellow at the Marian Koshland Science Museum of the National Academies. He has also held research assistant positions at the Converging Technologies Bar Association and FasterCures/The Center for Accelerating Medical Solutions.

CARL MITCHAM is Professor of Liberal Arts and International Studies at the Colorado School of Mines, Golden, CO. He has held previous positions at Pennsylvania State University and Brooklyn Polytechnic University. Most recently, he served as editor-in-chief for a four-volume "Encyclopedia of Science, Technology, and Ethics" (Detroit: Macmillan Reference, 2005).

ERIK PARENS is a Senior Research Scholar at The Hastings Center, a bioethics research institute in Garrison, NY. He also is an Adjunct Associate Professor at Vassar College, in the Program in Science, Technology, and Society. After receiving his BA, MA, and PhD degrees from interdisciplinary humanities committees at the University of Chicago, he taught philosophy and the humanities at The University of Delaware, Villanova University, University of North Carolina-Greensboro, and Wabash College. Since arriving at The Hastings Center in 1992, he has led research projects that have resulted in many publications, including 4 edited volumes: *Enhancing Human Traits: Ethical and Social Implications* (Georgetown University Press, 1998); *Prenatal Testing and Disability Rights* (Georgetown University Press, 2000); *Wrestling with Behavioral Genetics: Science, Ethics, and Public Conversation* (Johns Hopkins University Press, 2005); and *Surgically Shaping Children: Technology, Ethics, and the Pursuit of Normality* (Johns Hopkins University Press, 2006). He currently is developing two new projects, one on "The Uses and Misuses of Neuroimaging Technologies" and the other on "Pharmacologically Shaping Children."

PAUL M. PRIVATEER's work focuses on sociopolitical, cultural and ideological effects of science and technology. His recent book is *Inventing Intelligence: A Social History of Intelligence* (Blackwell, 2006). His current research explores the role human neurological and immunity systems played in the creation of human culture. "The Virtual and Viral: Studies of the Bio-Ideology of Postmodern Culture" deconstructs the four most dominant forces in postmodern culture—the digitalization of capitalism, the pervasive authority of information technology and networks, globalization practices, and the posthuman techno-mediated body—showing how each can be explained by the virtual and viral—the power to abstract and immunize. He is also the North American editor of the *British Journal of Educational Technology* (Oxford-Blackwell). His other volume, "I" (University of Georgia, 1991), explores the ideological trajectories of social modes of identity construction. He has written several articles, given international and national keynote presentations, and has appeared on BBC, CNN, ABC, NPR, and PBS and in *NY Times* and *USA Today* articles. He has chaired the Interdisciplinary Humanities Program, received a Fulbright, and been a visiting professor at MIT and Stanford. He received his PhD from the University of California, Davis, in Poststructural Theory and 19th century Literature.

JASON SCOTT ROBERT is Assistant Professor of Life Sciences in the School of Life Sciences at Arizona State University. He teaches in the Bioethics Program within the Center for Biology and Society, and is a faculty affiliate of the Consortium for Science, Policy, and Outcomes. Jason's PhD is in philosophy (McMaster University, 2000), and prior to joining the faculty at ASU, he was a Canadian Institutes of Health Research New Investigator and Assistant Professor in the Department of Philosophy at Dalhousie University. He has published many articles in the philosophy of biology and bioethics, and his first book, *Embryology, Epigenesis, and Evolution: Taking Development Seriously*, was published by Cambridge University Press in 2004. Jason has been recently preoccupied with determining the roles and responsibilities of scientists and bioethicists in the face of controversial science, such as the creation of part-human chimeras in stem cell biology. He is the co-leader of the Human Identity, Enhancement, and Biology theme of the Center for Nanotechnology and Society at ASU, focusing initially on the ethical and societal dimensions of the development of neural interfaces for therapeutic and enhancement purposes.

DANIEL SAREWITZ is Director of the Consortium for Science, Policy and Outcomes. His work focuses on understanding the connections between scientific research and social benefit, and on developing methods and policies to strengthen such connections. His most recent book is *Living with the Genie: Essays on Technology and the Quest for Human Mastery* (co-edited with Alan Lightman and Christina Desser; Island Press, 2003). He is also the co-editor of *Prediction: Science, Decision-Making, and the Future of Nature* (Island Press, 2000) and the author of *Frontiers of Illusion: Science, Technology, and the Politics of Progress*, (Temple University Press, 1996). He has also written many other articles, speeches, and reports about the relationship between science and social progress. Previously, he was the director of the Geological Society of America's Institute for Environmental Education. From 1989-1993 he worked on Capitol Hill, first as a Congressional Science Fellow, and then as science consultant to the House of Representatives Committee on Science, Space, and Technology, where he was also principal speech writer for Committee Chairman George E. Brown, Jr. Before moving into the policy arena he was a research associate in the Department of Geological Sciences at Cornell University, with field areas in the Philippines, Argentina, and Tajikistan. He received his PhD in geological sciences from Cornell University in 1986.

WENDY SHANEYFELT is a computer software researcher in Sandia National Laboratories' Cognitive Systems group. Her current work focuses on cognitive technology applications that model human cognition, detect patterns and anomalies in large data sets, and effectively train students using cognitive models of subject matter experts. She has developed ethical principles and guidelines for the development of cognitive systems and is structuring a plan to apply these mechanisms to real-world challenges.

JOSHUA SCHULMAN currently serves as an Advisory Scientist for neuroscience programs at the Defense Advanced Research Projects Agency (DARPA). In this capacity, he is the Technical Director for the Neurotechnology for Intelligence Analysts program as well as other projects in cognitive systems and neuroscience. Previously, Dr. Schulman was the Bernard B. Levine postdoctoral fellow at New York University where he studied human neuropharmacology using magnetoencephalography. He holds a BA in English and Comparative Literature from Columbia and a PhD in Physiology and Neuroscience from New York University. During his graduate training in the laboratory of Dr. Rodolfo Llinas, Dr. Schulman was awarded a National Research Service Award from NIH to support imaging studies in the neurophysiology of psychiatric disorders and neuropathic pain. He is a member of the Society for Neuroscience and the New York Academy of Sciences.

PETER J. WHITEHOUSE is Director of the Office of Integrative Studies, Department of Neurology at Case Western Reserve University as well as Professor of Neurology, Psychiatry, Neuroscience, Psychology, Nursing, Organizational Behavior, Cognitive Science and History. He is a geriatric neurologist, clinical cognitive neuroscientist and "global" bioethicist. His integrative clinical practice is built around the power of stories to assist those with aging associated cognitive challenges. His main interest is developing innovative clinical and learning environments to promote individual and collective health and wisdom. He has written on the ethics of cognitive enhancement and conducted clinical trials.

GERRY YONAS is Principal Scientist and Vice President at Sandia National Laboratories, where he founded (in 1999) and directs the ACG. His career began at the Jet Propulsion Laboratory in 1962 as senior scientist. In 1967, he joined Physics International and was responsible for investigating the physics of high power electron beams. In 1972, he joined Sandia National Laboratories where he initiated and directed the particle beam fusion program and the particle beam weapon program. In 1983, served as Chairman of the Directed Energy Weapon Panel of the "Fletcher" study that formed the basis for the Strategic Defense Initiative Program. He served as the first Chief Scientist and Acting Deputy Director for the Strategic Defense Initiative Organization from 1984-1986. In 1986, he joined Titan Corporation as President of Titan Technologies. he rejoined Sandia in 1989 as Director of Laboratory Development, and, in 1991, he became Vice President of Systems Applications, where he focused on strategic leadership in new initiatives in global surveillance, battlefield sensors, and non-nuclear high precision weapons. In 1995, he became VP of Systems, Science, and Technology. After completing a BS in Engineering Physics at Cornell University in 1962, he received a Guggenheim fellowship for graduate study at California Institute of Technology and received a PhD in Engineering Science and Physics in 1966. He is a Fellow of the American Physical Society and a Fellow of AIAA. Awards include: USAF "award for meritorious civilian service" for his contributions as a member of the USAF Scientific Advisory Board; BEAMS prize "in recognition of his original contributions to the field of particle beams…," IEEE Peter Haas Award for "outstanding service to the field of pulsed power technology;" Fusion Power Associates Leadership Award "for development of pulsed power technologies for fusion power and national defense applications;" and Secretary of Defense Medal for Outstanding Public service for "exceptionally meritorious service to his country by significant contributions to the nation's Strategic Defense Initiative." He holds a U.S. Patent for a Relativistic Electron Beam Accelerator concept. He has been a member of the U.S. Special Operations Command Science Panel, the U.S. Army Science Assessment Group, the Senate Select Committee on Intelligence Technical Advisory Group, and the Center for Strategic & International Studies Commission on Global Aging, the Advisory Council for the School of Electrical and Computer Engineering at Cornell University, and the Electrical and Computer Engineering Advisory Council at the University of New Mexico.

FACILITATORS

IRA BENNETT is a post-doctoral researcher at the Consortium for Science, Policy and Outcomes and the Center for Nanotechnology in Society who is studying policies and politics of emerging technologies specifically nanotechnologies. His projects include: educational programs in Nanotechnology in Society, explorations in State and Regional investments in Nanotech, and maintaining an international network of social scientists studying nanotechnology (International Nanotechnology and Society Network). Previously he was a post-doctoral researcher in the Department of Chemistry and Biochemistry at Arizona State University, working with de novo designed peptides directed towards the development of bio-compatible catalysts. Dr. Bennett completed his PhD in Chemistry in 2003 developing artificial photosynthetic membranes capable of metal ion transport. This work occurred at ASU as part of a NSF funded Research Training Grant focusing on Bio-molecular Devices after receiving a BS from The Evergreen State College in Olympia, Washington.

CORY DILLON is an organizational consultant with a background in leadership development and talent management. She has more than 25 years' experience in strategic planning, group facilitation, and primary and secondary market research. Cory provides organization and support for CNS activities, programs, and projects, including "back office" functions, and represents CNS at ASU and in the community. As the unit matures she will coordinate marketing, including CNS web site and other media outreach strategy; research and analysis; report and proposal writing; and fundraising and special events. Cory earned a BS in Business Administration and a master's in healthcare administration, both from Ohio State, and a master's in pastoral studies, emphasizing organizational development, from Loyola University of New Orleans.

LORI HIDINGER has served as Program Manager for CSPO since July 2004 and is a member of the Science Policy Assessment and Research on Climate project team. Prior to joining CSPO, she was a program manager with the Ecological Society of America's Sustainable Biosphere Initiative Science Program's Office where she was responsible for managing a number of projects that sought to develop or define the science of ecology to inform management and policy decisions. Ms. Hidinger served on the Program Committee for ESA's conference on "Ecology in an Era of Globalization." In addition, she participates in the Sustainable Rangeland Roundtable, for which she serves on the Steering Committee and co-chairs the Outreach Working Group. She also served as Chair of the Society for Range Management Nominations Committee. Lori received her Bachelor's of Science in Zoology from the University of Maryland and her Master of Environmental Management in Resource Ecology from Duke University 's Nicholas School of the Environment.

ERIK FISHER is a research faculty member of the Center for Science and Technology Policy Research at the University of Colorado at Boulder, where he also teaches humanities for the Farrand residential academic program and collaborates as an "embedded humanist" on nanotechnology projects in the Department of Mechanical Engineering. His research investigates the possibility and utility of integrating societal considerations into R&D, as called for by the 21st Century Nanotechnology Research and Development Act of 2003. He is also interested in engineering education, technology assessment, philosophy of technology, and policy implementation. From 1999-2003 Mr. Fisher was the Humanities Advisor for the College of Engineering and Applied Science, where he developed programs to integrate humanistic thought and societal considerations into the engineering curriculum. These included an in-house online writing lab and a variety of interdisciplinary courses, each one team-taught by both engineering and humanistic instructors. In 2002, he received a Humanities Focus Grant from the National Endowment for the Humanities to explore dialogue between the "two cultures" of science and the humanities. He holds a BA in philosophy and mathematics from St. John's College (Annapolis, MD) and an MA in Classics from the University of Colorado, where he is currently completing a doctorate in Science and Technology Policy through the Environmental Studies program.

RECORDERS

KALIL ABDULLAH is a research intern at the Center for Nanotechnology and Society (CNS). His specific interests at CNS lie in the role of nanotechnology in cognitive enhancement, and the legislative process of science policy outcomes. Prior to attending ASU, Kalil spent time at the University of Hawaii researching the applications of bacterial genetics in aerospace as a NASA Space Grant recipient. Upon arriving at ASU, he began an internship at The Barrow Neurological Institute investigating spinal motor systems control and motorneuron properties of spinal cord injury, a research project that he is currently undertaking. Kalil also works for the Donor Network of Arizona as an Ocular Recovery Technician, procuring healthy organ and tissue from donors so that they can be made readily available to those in need. He is also the founder of the ASU chapter of *The Triple Helix*, the international journal of science, society, and law, which is sponsored in part by CNS. He plans to graduate from ASU in May of 2007 with a degree in Molecular Biotechnology.

JENNY BRIAN is a graduate student in the Bioethics, Policy, and Law program at the Center for Biology & Society, at the School of Life Sciences. She comes to ASU from her position as a Research Associate in the Program of Biology, Ethics, and the Politics of Human Reproduction at Wellesley College, in Wellesley, MA. Before that, Jenny worked as a Research Assistant in the Departments of Bioethics and Philosophy at Dalhousie University. She graduated from the University of Western Ontario in 2003, where she received her BA (Hons) in Philosophy with a Minor in Ethics. Her research interests include: the intersection of science, politics, and ethics; global health and global justice; and innovation and the commercialization of scientific research.

RYAN MEYER is a graduate student at ASU's School of Life Sciences and the Consortium for Science Policy and Outcomes, and a Research Associate in the ASU Office for Sustainability Initiatives. He arrived in Arizona in the fall of 2005 after spending three years working as a Program Manager at the Earth Institute at Columbia University. Prior to that, he received his BA in Biology from Bowdoin College, where his focus was ecology and marine biology. Ryan's most general interest is in how disciplines frame problems and determine what qualifies as valid knowledge or acceptable fact. His work at CSPO focuses on how conflicts among these differing perspectives influence deliberation and decision making, with particular focus on uncertainty in debates over climate policy and climate science policy.

MARK NEFF received an MS degree in Environmental Studies from the University of Oregon, where his research focused on using scenario analysis as a tool to aid in ecological management decision making in politically charged and uncertain situations. He joined ASU and CSPO in the fall of 2005 to work toward a PhD in the School of Life Sciences. His research focuses on science policy and ecology, and is part of the Ecosystem Sensitivity Analysis component of CSPO's Science Policy and Research on Climate project.

ZACH PIRTLE is a senior majoring in philosophy and mechanical engineering, and serves as a research intern for the CNS. In addition to the CNS, Zach has also worked for Honeywell Aerospace and the Center for Biology and Society. His honors thesis is dedicated to understanding the societal implications program for nanotechnology as was mandated by the 21st Century Nanotechnology Research and Development Act.

RACHEL SMITH graduated from Arizona State University with a BS in Biology and Society. As an undergraduate, she worked as a research intern for the Consortium for Science, Policy & Outcomes and the Center for Nanotechnology in Society and is currently a management intern for both organizations. Her current major project is an analysis of state-based nanotechnology initiatives. She spent the first three months of 2006 volunteering in a hospital in Cochabamba, Bolivia and will attend the Indiana University School of Medicine beginning Fall 2006.

BRIAN YOUNG is currently pursuing a post-baccalaureate in Biology and Society with an emphasis on environmental ethics and policy. Previously he obtained a BA in Political Science with a minor in Philosophy from ASU in 2005. He joined CSPO in the fall of 2005 and is working for CNS developing scenarios of future nanotechnologies.

CSPO WORKSHOP ORGANIZER

NICOLE HEPPNER graduated from Arizona State University with a BS in Biology & Society and a minor in Spanish in December 2005. As an undergraduate she worked as a Research Intern for CSPO and following graduation, Nicole worked at CSPO as a Management Intern where her responsibilities included doing research for CSPO-related projects; managing the websites; and helping to organize workshops and conferences. In the fall of 2006 she will begin the Masters of Public Health program at the University of Minnesota , where she will major in Epidemiology. In general, she is interested in the influence of a multitude of factors (political, socio-economic, cultural, geographical, behavioral, etc…) on achieving health goals locally, nation-wide and globally. Her research interests include infectious disease, global health, public health trends, disease prevention, inequities in health, and health policy.

ACG WORKSHOP ORGANIZER

SUMMER JEROMIN supports and coordinates the Sandia Advanced Concepts Group Fests (workshops), assists with the ACG's newsletter, and is a member of the ACG team working on science and technology education issues. She holds degrees from Wheaton College (IL) and St. John's College (NM) and has several years of experience as a secondary English teacher at North Hills Classical Academy (Grand Rapids, MI).

REPORT AUTHORS

DANIEL SAREWITZ and THOMAS H. KARAS

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