CHAPTER 1

The View from Congress: A Roundtable on Nanopolicy[1]

U.S. CONGRESSMAN MIKE HONDA, U.S. CONGRESSMAN BRAD SHERMAN, U.S. CONGRESSMAN DAVID WELDON, and MARTY SPITZER[2]

MARTY SPITZER

I am here representing the Chairman of the Science Committee, Mr. Boehlert, who has other obligations in the District today.

What I would like to do today is to: provide a little bit of an overview of three things; tell you a little bit about what the Science Committee has been doing and is doing in the area of the societal and environmental implications of nanotech; provide a quick overview of what the 21st Century Nanotechnology Research and Development Act, which created the federal apparatus to implement and carry out the Act, requires; and then talk to you about one element of the societal implications that everyone has some interest in and that is pressing upon us today—the environmental implications.

When the Act was passed in 2003, basically, it authorized almost $4 billion over 5 years to be spent by the federal government. It provided the statutory framework for what a lot of the federal government is doing today. So, it set up interagency committees, required annual reports to Congress, and set up an advisory panel that would report every 2 years. One of the things that some of the other panel members can speak to is that it specifically called for an emphasis on research as it relates to the societal implications of nanotechnology in order to understand the impact of these products on health and the environment. It also includes a study that's almost done, on the responsible development of nanotech. This is part of

[1]Edited transcripts from the policy panel at the Center on Nanotechnology and Society's Nanopolicy Conference at the National Press Club, Washington, DC, on April 28, 2006.
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the triennial review that the National Academies of Science, and it is a one-time assessment to look at standards, guidelines, and strategies for ensuring the responsible development of nanotech. It is supposed to look at including issues of self-replicating nanoscale machines and devices, as well as the release of such machines into the environment.

The other piece of the societal implications is the environmental aspects of nanotech. There are really two components of that. There are the environmental applications, that is, technologies that are actually going to help to make the environment cleaner and better. Then there are the environmental health and safety implications, those things that may actually cause problems for humans, the environment, and our ecosystems. What I am going to do is spend some time talking more about these implications.

Now, the federal investment is approximately $1.1 billion, up from almost $500 million just a few years ago. That is matched with a lot of private-sector funding that is on the order of $2 billion, close to half a billion dollars per year in state funding, and then international investments in the arena of nanotech; the numbers are quite significant. The context for talking about environment—and really all the societal implications—is the potential growth of this sector, in terms of the entire economy. The numbers being tossed around are enormous. Lux Research predicts that, in 10 years or so, $2.6 trillion worth of products in the global marketplace will contain nanomaterials and 15% of manufacturing output will include some nanomaterials. This is enormous, and it puts a great deal of pressure on all of the systems (societal, business, infrastructure, and governmental) to deal with the changes that this new set of technologies will bring about. So it's in that context that we have been, as a Committee, thinking about the environmental implications. The initial concern is: Are we spending enough, and are we doing enough in this arena? So far, in Fiscal Year 2006, approximately $80 million of the federal investment was devoted to societal implications of nanotech. About 4%, or $38 million, of that was devoted to environmental implications, and most of that came under the oversight of the National Science Foundation, where they do investigator-driven research. The rest of the funding has been spent on economic workforce, educational, and other ethical issues. We are still waiting to hear what the 2007 proposed budget figures will be. Hopefully, we will have those pretty soon. And there is lots of private-sector money being spent, as well.

We are talking about a suite of technologies that are going to revolutionize the way we do things and how we live. And the questions are How will that happen? And what will we do as this unfolds? Do we have systems in place that are capable of keeping up with the rapid change of the technology?

In the environmental arena, we are dealing with two kinds of problems regarding nanotech. I am assuming, for a moment, that everyone agrees that there are probably some beneficial uses of nanotech, and that there are very good things that we are going to be able to do with them. Yet we have both real and perceived risks with which to deal. Among the real risks, it is probably true that most nanomaterials aren't going to be very harmful. Although there is early evidence that some of them are. So, the question is How do we distinguish them? It is not hard to

imagine that the very elements that make the nanomaterials so beneficial and so exciting in their applications, their small size and their unique behavioral characteristics, are the same things that potentially make them dangerous to humans and the environment.

When the Woodrow Wilson Center did its study last year looking at the public perceptions of nanotech, it found a couple of things that were important and should guide us as we are thinking about how to move forward. The first is that the public generally does not know much about nanotech, but, when it does learn more about it, it is actually pretty optimistic. But, at the same time, when there is a void and the public does not have information, people tend to fill that void with other experiences (e.g., dioxin, nuclear power, and asbestos): think superfund and hazardous waste problems. And, if we leave that void there for too long, you can be sure that it will be filled with negative experiences. So, on the positive side, the public is reasonably positive toward nanotech when it does not know much about it. But, it also wants to make sure that there is a strong governmental role and a strong regulatory framework that ensure protections are in place. And the public just generally doesn't trust voluntary approaches to solve those kinds of problems. So the lesson, I guess, for the short run, is that there is time to shape public opinion, but, at the same time, we have to provide the public with the information that it really needs.

Many businesses have learned the lessons of not doing that, and I think that's one of the major reasons why there's so much consensus among the business community, the environmental community, and many regulators and government officials about the need to move and as quickly as possible. So, the common ground that we need for moving forward, in some sensible way, is really in place. The problem is that we actually do not have the information we need to make those decisions. Some of the things we are missing include a standard nomenclature; basic tools for measurement, toxicity screening, and risk characterization; and tested personal protective equipment for workers. And, even if we had all those things, we would have to think about them in a lifecycle framework. We cannot just think about workers; we have to think about products and their uses, and what happens to them at the end of their lives. We're seeing more and more examples of things that may give us some concern. When the Wilson Center did an inventory of the nanoproducts that are out there, it discovered more products than people thought are actually in the marketplace. The recent case in Germany regarding the "nano" product recall raises a whole bunch of questions that, actually, we cannot answer yet and that we cannot even get the basic facts about.

What has become clear from the Science Committee's standpoint is that we need a comprehensive research strategy. And we believe that was called for in the Act, and the federal government is in the process of putting together its version of what it thinks that ought to be. The Committee is going to hold a hearing when that report comes out. It's a little delayed from what we were hoping, and we're hoping to see something soon. That's going to give us something to look at and decide: if we are on the right track; if we are doing this at the right scale; and if we need to do more.

The Environmental Protection Agency (EPA) recently published a white paper that started to look at its regulatory framework. This is very important, not just for the EPA, but for the other agencies involved, the Federal Trade Commission and a variety of agencies.

As we think about those questions, I will just leave you with two last thoughts about some of the public policy and the bigger picture policy questions that must be addressed. One is, of course, as we deal with this industry, we are dealing with a lot of small companies. These are the start-ups that are developing these materials. They are not the large chemical companies that are used to regulation and that are used to having systems in place to deal with problems. Thus, we are going to have to make some special arrangements for and give some special attention to this sector. And there are a number of products that we are actually talking about using whose purpose is to be dispersed into the environment. We must grapple with what we are going to do and our assumptions about the appropriateness of that before we actually have the answers to the scientific questions that we must answer.

So, in closing, I would like to reiterate that we are making progress on these issues. In fact, in this arena, my experience suggests that we are making progress faster than we have ever made in any other area. That is a positive sign. And the community of interest shares common ground about the need to move forward. So the questions are: What do we do with that goodwill? How do we make the most of it? How do we direct our science and research effort to answer those questions as quickly as we can?

U.S. CONGRESSMAN DAVID WELDON

I practiced medicine for many years. Indeed, I still see patients about once a month in my congressional district. My undergraduate studies were in biochemistry, and I did some basic science research. I have always been very interested in issues of science, and I have actually been quite interested in the emerging field of nanotechnology, really from its infancy. I began reading about it more than 10 years ago in some of the science publications that I study. And I was certainly delighted when Congressman Honda helped move forward the legislation that got funding going for the technology. My particular areas of interest, as you can imagine, are nano's medical applications, as well its aerospace applications, as I represent the area of Florida that includes Cape Canaveral and Kennedy Space Center. I think there is a tremendous amount of potential for applications in our space program, and, obviously, we have all been talking for years about applications in medical technologies.

I think the Congress, when it originally funded this program, envisioned—at least based on my discussions with colleagues—a robust discussion of the ethical issues, as well beyond the toxicology and the environmental issues. And, specifically, I believe that a percentage of the funding should be devoted to the ethical, legal, and social implications. Now, what I mean by that is that I believe there should be a discussion of some of the fundamental issues associated with human

dignity and the development of ethical guidelines that can set practical boundaries as we apply nanotechnology in the United States. In addition, there should be the development of a process in which these ethical guidelines can shape our funding decisions as the Congress moves forward in the years ahead to continue the funding.

My interest really got piqued tremendously when I read a federal publication talking about a whole host of potential human enhancements—impacts that could enhance memory, muscle strength, and coordination. When you start moving into a discussion beyond helping the blind to see or helping the crippled to walk, you are talking about the potential capabilities of applying these technologies to create human enhancements. I believe an ethical discussion needs to be conducted *now*—not when there is a private company, the licensing has already moved forward, and the funding has occurred 10 years prior.

When we had Dr. Marburger in front of the Science and Commerce Subcommittee that I am on, he shared a very interesting little vignette about the iPOD. The basic science funding that went into making that device possible is fascinating. I have one, but I did not know its background. It was funding not only from the National Science Foundation; you could trace back funding to the National Institutes of Health, the Department of Defense, and the DOE, which allowed the development of the technologies that went into creating this device. I say all of this just to make the point that we do not know where all this is going to go: We really do not. There could be some really wonderful breakthroughs that not only help people with problems, our defense department, our national security, and the war on terror, but they could, at least as has been the case with the iPOD, create whole new industries that employ thousands of people. So it is really an exciting field.

And it is great to be part of this at the ground level. I think some great things are going to come out of it. But I want to begin the ethical discussion, particularly of human-enhancing technologies, today. Let's have a vigorous debate or discussion on how these technologies could or should be applied. Here are some of the questions that I think we should be asking, and I would like to see them addressed in the near term:

- Should a distinction be made between treatment and enhancement? If so, what limits, if any, should be placed on research on human enhancement?
- In light of the President's concern that we not go down the route toward a Brave New World, and repeated statements by policymakers about the importance of safeguarding the human condition, to what extent could nanotechnology impact human dignity and integrity? And how can we best ensure that the development of nanotechnology in the United States supports existing bipartisan commitment to human rights and human dignity?
- What unique privacy concerns arise with the advent of nanotechnology? And what kinds of protections are necessary individually and societally to ensure that nanotechnology proceeds in society's best interests?
- How are ethical issues related to nanotechnology being addressed globally?

- And, finally, what are the policy implications of the emerging ethical issues related to nanotechnology? In other words, how does this bounce back to us? Do we need laws? Do we need regulations? Do we need congressional action?

Don't ask me to answer all of these questions. That's your job, and I am looking forward to hearing your thoughts.

U.S. CONGRESSMAN BRAD SHERMAN

I am Brad Sherman from California's best named city, Sherman Oaks. The year 2006 is my tenth year in Congress, my fourth year on the Science Committee, and my eighth year of worrying about something I call engineered intelligence, for which I will get to a definition in just a second.

First, a few observations. Nanotechnology is the hip new term for, really, all cutting-edge science. We owe a great debt of gratitude to the GMO-phobics who have illustrated for the scientific world why it is so important to discuss societal issues in a broadly based way. Science is not just for the scientists and the venture capitalists. Nanotechnology raises consumer safety issues; it raises environmental safety issues.

Others are discussing those issues. Congressman Weldon and I, I think, are focused on issues outside of that realm. My focus is on engineered intelligence, by which I mean either computer engineers developing a level of self-awareness and intelligence that surpasses human intelligence, or biological engineers creating new types of human beings or new types of mammals with superhuman or beyond-human intelligence. So whether it is the computer engineers using what could be called "dry nanotechnology" to give us HAL, or the bioengineers using "wet nanotechnology" to give us a 2000-lb mammal with two 50-lb brains capable of beating your kids on the LSAT, nanotechnology raises the question of whether humans, as we know them, will be the most intelligent species on this planet by the end of the twenty-first century.

I used to say that the last decision humans would make is whether our successors are carbon based or silicon based: Whether we will invent a superspecies through a computer or through biological engineering. Since then, I have learned a little bit more about science, and I have a couple of corrections. First, the future of computers is probably not a silicon substrate. And we are probably, before we face completely nonhuman and superhuman levels of intelligence, going to face the enhanced human: The chip in the brain that Dave alluded to. I call this "damp nanotechnology": A combination of DNA on the one hand and computer engineering on the other.

Mike Honda really played the key role in getting the 21st Century Nanotechnology Research and Development Act passed. My focus was on making sure that, whether it is the creation of self-aware machines, the enhancement of human intelligence, or other deoxyribonucleic acid (DNA)-based forms of intelligent life, that these be included in what is studied when we study the societal implications of

nanotechnology. Since then, I have been working with the Defense Advanced Research Projects Agency (DARPA) on this, and a report should be issued soon. The NSF has decided to fund the Center for Nanotechnology in Society there at Arizona State University. And I have got to commend Congressman David Weldon for getting money in the appropriations bill specifying that a percentage of funds, in this case 3%, ought to go into looking at societal implications.

Now, let's put this into context in terms of the history of science. The twentieth century was a century of enormous scientific development. It allowed us to quintuple the human population in one century: Pretty good for a large land animal, even Darwin would have to admit. The most important of those scientific developments, or certainly the most explosive, was the development of nuclear weapons and nuclear technology. And I believe it is just about the only analogy we have to what will be the import of developing engineered intelligence. Einstein wrote a letter in 1939 to Roosevelt, and it is the first evidence I have seen of a top decision maker focusing on the implications of nuclear weapons. Six years later—with almost no societal thought, some thought among the scientists, and no involvement of society as a whole, or theologians, or philosophers—we had Hiroshima. Now, when nuclear weapons came to the fore, we saw them in the big form. We can imagine what the history on nonproliferation could have been if the first nuclear weapon had been half a kiloton, like the briefcase bombs that they talk about. But instead, humankind was confronted with nuclear weapons in their obvious import as we began to catch up—as the diplomats, the theologians, the philosophers, and society at large—tried to wrestle with the issue of how do we deal with nuclear technology.

When it comes to engineered intelligence, there are some substantial differences. One is that I expect that this technology will creep rather than explode. That is to say, I think we are going to see the chip in the brain before we see HAL or an existential elephant—meaning a super-large mammal with a super-large DNA brain. That prospect will make it harder to get society to concentrate on these potential issues. On the other hand, we have got a lot more lead time. It is not just 6 years from when decision makers and society as a whole become aware of the issue, and when the technology presents itself in all of its glory.

Today, the good news is We have got about 150 people here at this Center on Nanotechnology and Society Conference. Likewise, the bad news is We have about 150 people here.

However, I do not think that it was until the late 1940s that you could get a conference like this one to discuss the implications of nuclear weapons. That was well after Hiroshima. We had a panel before the Science Committee saying we are about 25 years away from engineered intelligence through computer engineering. But, it is probably a lot less until we face the chip-in-the-brain issues.

Now, like my colleagues, I do not have any answers. Rather, I hope to identify some of the questions. I know that the right time to start thinking about these questions is now. Do we want to create self-aware machines? And if so, what societal rights will those self-aware machines have? What is the definition of a human? As David Weldon points out, What level of chip enhancement do we find acceptable? Will computers that are superintelligent be self-aware?

I have asked DARPA to take a look at what steps we would take to engineer the maximum possible intelligence, while preventing (or seeking to prevent) self-awareness. If we have a self-aware computer, will it be ambitious? We are used to DNA-driven devices, life that is inherently ambitious, whether it is human or the smallest, least sophisticated creature. These are creatures that wish to survive and seem to wish to propagate—and may even wish to control. In contrast, my washing machine does not care if I turn it off, and I am not sure that a computer capable of an existential crisis will care whether that crisis is interrupted by an off switch. In contrast, the DNA work starts with raw material that is inherently ambitious, and I do not know if we understand it enough to deprogram such ambition, even if we wanted and decided to do so.

Then, we raise the issue of whether we start with human DNA, which raises all the stem cell issues and all those politics, or whether we start with chimp DNA. All I know is that the last time a new level of intelligence was on this planet, it was when our ancestors said Hello to Neanderthal. It did not work out well for Neanderthal.

We have got to address these questions, and it is going to take a lot longer than 6 years to address them. So, thank God we've got longer than 6 years. It will take better minds than mine to figure them out. But my hope is that these questions can be worked out with merely human intelligence.

U.S. CONGRESSMAN MIKE HONDA

Good afternoon. This is a fun place to be because we get to listen to all these questions that both Congressmen David Weldon and Brad Sherman bring up.

I think these are the kind of questions we thought of and we struggled over as we developed the bill that was the 21st Century Nanotechnology Research and Development Act. That bill would not have been successful without the guidance of Chairman Sherwood Boehlert. When we got together to do the bill, I asked him: "Do you think this bill will get through?" He said, "I am the chairman." So, here we have the formula for success for bills in the areas that we care about. We have a bipartisan approach, we have someone on appropriations who understands this stuff, and so things can work together.

I think that what we can agree upon today is one of the pieces that was important to me in forming that bill: the issue of education in ethics. That is really the issue of the public as we move along in this particular science. And as Brad has very well pointed out, we take lessons from the past, and we must be aware of what can happen when we do not listen and do not discuss things in an open, public way. Sometimes science can get ahead of us, in terms of our sense of propriety. This whole issue of nano goes to what I call the "Mork and Mindy" approach; you recall that on that show Robin Williams' character, Mork, often said: "Nano, nano." That was the first time you probably heard the term nano in a public realm. Since that time, we have moved on to higher expectations from what we all now understand nano stands for. The media has a great role, in terms of public education and all these things we care about. So, as policy makers and Americans,

we should be having more public discussions, such as this one, and we should also be bringing along members of the media, who can accurately share the information that we are talking about and engage the rest of the public in this discussion.

Everybody who comes to my office to talk about nanotechnology talks about what their organization does and their efforts on the science side of the technology, and I always ask them what they and their organization is doing in the area of ethics. I spoke at speak a conference in 2004, where I addressed the responsibility that scientists and policy makers have to engage with the public in a discussion about this technology early on, before problems are upon us. At that time, I made a point about how the debate about stem cell research might have proceeded differently had such a conversation taken place and that I want to prevent the same thing happening in nanotechnology.

Today, I want to make a point about a difference I see between stem cell research and nanotechnology: one which I think bodes well for our chances of making more progress on reaching more of a consensus about nanotechnology. In comparing the ethics of stem cell research to those of nanotech, I think we should look at two separate sets of ethical questions that arise from stem cell research. One set of issues is the fairly intractable one that arises from the use of embryonic stem cells. Those of us in this room, like people across the nation, have fundamentally different views on when life begins. What this means is that some of us feel that it is acceptable to use stem cells from embryos, which destroys them in the process, while others of us believe that destroying embryos is destroying life, which is wrong. These are two very different, polar positions, and resolving them is quite challenging. The standoff has led to different policies at the state and federal levels, depending on which mindset has the majority in that jurisdiction. I am not going to try to solve this problem here. Congressmen Weldon and Sherman have quite aptly already stated that we are not here to solve these problems. But, rather, we know how tough the issues can be. As a result, I would rather look at the other set of ethical questions that comes with stem cell research. And, in this case, we can benefit from thinking about the kind of stem cell research that is more widely accepted, research that uses adult stem cells in which no embryos are destroyed, thus eliminating that issue away. I think those of us in this room, regardless of our position on embryonic stem cell research, can agree about the potential benefits of adult stem cell research, which might bring about new treatments and cures for disease. But there is still a set of ethical questions that goes along with even the use of adult stem cells. A big question in particular being How far should we go?

When I was listening to the discussion here today, I started to think about the movie, *The Island.* In that movie, there was a colony of people growing up and being well cared for, and, upon reflection, herded. It turns out that these people were being grown for purpose of providing replacement of organs for those people who live in the world beyond the Island who need such organs and have matching DNA. Those on the Island thought that when they left the Island that they were going to paradise and that they were being selected to go via a lottery system. But, actually, it was all by design. This movie represents the fact that we have the ability to bring up and explore a set of issues and questions through media, such as film.

For example, if I needed a new kidney and we could use adult stem cells to grow a new one, I think that we would all agree that this would be a good idea. But in the movie, the only way to get new kidneys was to grow a new me and then cut out those kidneys. I think we can all agree that that is not such a good idea, especially for the other me, who is a sentient being. And, so, we look at cloning human beings as probably a bad idea because it raises all sorts of ethical questions, especially with regard to harvesting organs.

There is a place to draw the line on things like that, and, similarly, I believe that we can find the lines to draw in the area of nanotechnology. I also think that it is essential that the conversation not just take place among scientists or policy makers, or even between those two groups. The general public has to live with this stuff. They are the ones who need to find it acceptable. So, we need to engage with the public as we try to figure out where and how the lines are to be drawn.

There are going to be extremes on both sides. Some will argue for no limits, maybe envisioning a world in which our minds and spirits might be separated from our physical bodies and able to live forever in a machine. Others will say that we should allow no biological applications of nanotech, and rather that nature should be allowed to run its course. Where we will end up is somewhere in the middle. We will find manufactured vaccines or treatments for diseases acceptable using human-grown biologics. Is an artificial nanoantibiotic that can kill bacteria really so far from that idea? I think that what we will find is that this will depend on how the nano antibiotic works. Some of the examples we might use include whether we can replace the eyeglasses that we use now to correct vision for those who have imperfect sight. The question is Is an artificial nano retina that improves eyesight really so far from that concept? Again, it will depend on whether it can provide performance that sees like a regular human eye or whether it lets you see new wavelengths and greater distances, in which case we are talking about something very different than just correcting a defect to a normal level. Again, if you are using the technology to restore hearing to the normal level of function that may well be accepted, whereas it is a whole new question if you are able to increase the frequencies one can hear, thereby enabling someone to eavesdrop on very quiet conversations, which we may not want. It might be fun as a school teacher to understand what is going on in the rest of the classroom. But it is still an ethical question. So we are going to have to look very carefully at the applications where nanotechnology is combined with biological systems and decide if we are willing to allow applications to improve human performance or not.

Such potential capabilities beg the question whether those applications would change what it is to be human? I refer back to two other movies, *I, Robot*, and *A.I.* The movie *A.I.* is about a young person who found out that he was a robot, and so he went on a quest to become more human. So the questions really are:

- Do we really want to allow these changes to take place?
- Is this something that people should have individual choices over?
- Is it really possible to have individual choice anyway?

- If one person does something like implanting a memory chip or math processor that would be implanted in the human brain using nanotechnology, does that mean that everyone else has to keep up?
- Who can afford it?
- Will there be a division among the people who can afford it and those who cannot?

These are weighty questions, and I do not pretend to have the answers. They are big questions and ones that we have to begin to pursue. So, what I believe we need to do is to educate the public as we move along and go point by point so that fear and anxiety does not overtake sound policy making. But educated input and good, robust debate must occur in this arena; that is what this democracy is all about. I believe that as thinking, feeling, and compassionate human beings, we will come to answers to these pressing questions by having these conversations, and, thus, I think that we will be able to guide technology. And, in the words of *Star Trek*, we will be able to go where no other man has gone before.