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Military Uses of Nanotechnology and Nanoethics

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Introduction

Ethical, legal and societal aspects (ELSA) of nanotechnology¹ have become important fields of research, in part because of the promises or threats of revolutionary technology, in part because, different from earlier times, government support of nanotechnology has included funds for such research from the beginning. Many different subjects are being covered (see the contributions to this symposium), but it is conspicuous that one area is largely missing: military applications of nanotechnology. There is one comprehensive book proceeding from the view of international security (Altmann 2006), and a recent one treats a sub-area from the view of national defense of the USA (Kosal 2009). Given that new military technology can have far-reaching consequences for peace and war and thus for the future of humankind, ELSA research should devote more effort to the study of military uses of nanotechnology.

This contribution explains and assesses military uses of nanotechnology and argues that they add new aspects to ethics. For an ethical appraisal, I explain relevant concepts: just-war theory, security dilemma, arms control and disarmament. After discussing the role of technology in general, I present potential military applications of nanotechnology and cast a look at military research and development. Preventive arms control is introduced as a concept and then applied to military uses of nanotechnology. I emphasize the pivotal role of the USA, consider the long-term future of the international system with nanotechnology and end with conclusions concerning research and ethics.

Just-War Theory and Humanitarian International Law

Just-War Conditions

When ethics is discussed with respect to armed conflict, it is often put in the framework of just-war theory (Walzer 1977/2006, Orend 2005, Moseley 2009). Situated between so-called realism which holds that states will go to war as it fits their interest and that moral considerations are irrelevant, and pacifism which assumes that all wars are bad and need to be avoided, just-war theory posits that some wars are morally justified, given that a set of conditions are met. These conditions concern 1. when it is justified to wage war and 2. how a war is to be conducted, sometimes 3. obligations for the situation after the war are explicitly added. The conditions are often coined in legal language: *jus ad bellum*, *jus in bello* and *jus post bellum*, but only the second has full legal weight: the rules of war are defined in international humanitarian law, and there are international tribunals and a criminal court to punish perpetrators.

The obligations forming the *jus ad bellum* are: there must be a just cause (for example, defending against aggression); the war must be the last resort; the decision has to be made by a proper authority with a public declaration; the state must have the right intention; there must be a reasonable probability of success; and the means must be proportional to the end. These conditions are of course somewhat vague and not necessarily consistent with each other. For example with respect to the fourth condition there is the argument that if small countries as victims of aggression by large ones would always immediately surrender because defence would be overrun fast, this would invite bullying and weaken the international order.

¹ Here a wide notion of nanotechnology is used, incorporating nanoscience and fields where nanotechnology converges with other areas of science and technology. So-called molecular nanotechnology (Drexler 1981, 1986) is not discussed because it is still hypothetical; for a treatment see Gubrud 1997, Altmann 2006: Sections 2.2, 6.2.

The *jus in bello* demands can be grouped in two general categories. One is discrimination – only combatants are legitimate targets of attack, civilians (and combatants *hors de combat*, for example unconscious or surrendering) are to be spared. However, collateral damage is acceptable to some extent. The other category is proportionality – the amount of force used must fit to the military goal; in particular, creating superfluous injury or unnecessary suffering is prohibited.

For a war to be just, all obligations have to be met. Both groups of conditions are independent of each other: the rules of war hold in any case, for example even in a war of aggression which is unjust according to the *jus ad bellum*.

International Humanitarian Law

To a considerable extent, the international law applicable to peace and war follows the just-war theory. Concerning *jus ad bellum*, until World War I states were free to go to war at will, for whatever reason. Efforts to ban war finally led to the United Nations (UN) Charter (1945) which prohibits the use or threat of force against another state. Acknowledging that such acts might nevertheless occur, the Charter introduced non-military measures (such as economic sanctions, Art. 41) and action by armed forces (Arts. 42-49) which the Security Council could use in cases of “threats to the peace, breaches of peace, and acts of aggression.” However, due to political differences and the veto power of the five permanent members of the Security Council, in the wars after 1945 the Charter mechanisms were only rarely used, and provisions about creating a Military Staff Committee (Art. 47) were never enacted. As a fall-back mechanism, the Charter states in Art. 51 that in case of an armed attack, “until the Security Council has taken measures necessary to maintain international peace and security”, states have “the inherent right of individual or collective self-defence.” This now is the international-law basis for states building up armed forces (and this is why ministries of war have been renamed ministries of defence after 1945). Mostly, the use of force by a state has been justified as defense against an aggression by another state. But what constitutes aggression? The international community has not yet been able to arrive at a definition. The question of definition and the one of judging the facts in a concrete situation are intensely political and loaded with interests. A mechanism for arriving at an objective legal statement who committed the first aggression, taking into account also indirect forms (for example, subversion or foreign intervention in civil wars) is still elusive (e.g. Buignion, 2002).

Concerning *jus in bello*, the laws of warfare – also called international humanitarian law – correspond to the postulates of just-war theory and over the decades have been developed, expanded and refined (ICRC 2009, Fleck 2008). Many special rules exist, covering, among others, certain weapons and munitions, protection of the environment, and treatment of prisoners of war. The legal body is quite firm, and the obligations hold for all sides in an armed conflict, independent of political considerations, who is the aggressor etc.

Military Preparations Can Lead to Wars – the Security Dilemma

In its focus of when a war is justified, just-war theory does not really take into view efforts at preventing war – this only shows up faintly in the condition of war as the last resort. An ethical approach to war and peace thus has to encompass questions of war prevention in addition. This includes an obligation to use all means available before taking recourse to the last resort. On a general level, states should follow policies of *détente* and cooperation, reducing rather than building up military threats. Here, however, a problem exists with the present international system. Different from the situation within countries, where the security of citizens is provided for by the state with a monopoly of legitimate violence, the international system fundamentally is still characterized by anarchy – no overarching authority provides security among countries. As a consequence, each country strives to achieve security by building up armed forces which could defend it in case of armed aggression by another country, and which by their existence

and readiness deter such aggression. Unless very special measures are taken, the build-up of armed forces for defense at the same time increases the offensive threat to other countries. In the process of each country working for its own security, thus as a result, system-wide the security of all deteriorates. This is the so-called *security dilemma* (Jervis 1978). It does not represent an unavoidable fate, though; several ways out of this dilemma exist. One is limitations on the armed forces which are agreed among the countries – this is called arms control. More fundamental is a defensive restructuring of the armed forces so that they are highly effective in defense while having only limited offensive capabilities. Economic and political cooperation can reduce motives for war, as can policies directed to solving underlying conflicts without recourse to violence. The ultimate solution of the security dilemma would be to install a democratically controlled world authority with a monopoly of legitimate violence, as it exists within most countries. At first sight, this sounds idealistic and far off, but future developments in nanotechnology may provide impulses in this direction (see Section 11). For the near term, however, it is arms control concerning certain military uses of nanotechnology that is needed.

Arms Control and Disarmament

Arms control is the reduction of military threats by substantive limitation of armaments and/or armed forces agreed upon between potential opponents (Bull 1961, Schelling/Halperin 1961, Goldblat 2002). Improved communication can also form a part. If mistrust between potential adversaries is still too high for arms control, the process can be started by agreeing at first on confidence and security building measures – to exchange information, limit maneuvers, or invite observers. Arms control began in earnest during the Cold War, under the threat of nuclear weapons and with the experience of crises leading to the brink of nuclear war. Arms control has three main goals: avoidance of war, reduced military spending and damage limitation should war nevertheless occur. Because some measures to limit damage or save costs could actually increase the risk of war, the first goal has to take precedence.

Many arms-control treaties were concluded in the Cold War and in the first years after its end, multilateral ones such as the Partial Test Ban Treaty (1963) and the Nuclear Non-Proliferation Treaty (1968), and bilateral treaties limiting strategic nuclear arms (SALT I/II 1972/1979, START I/II 1991/1993).²

Disarmament, on the other hand, is about reduction of arms, ideally to zero. Disarmament contains a continuum from abolishing certain classes of weapons (such as biological and chemical weapons by the respective conventions of 1972 and 1993 and intermediate-range nuclear missiles by the INF Treaty of 1987) to “general and complete disarmament”, a long-standing UN demand, reiterated as a goal in the preambles of many arms-control treaties; “general” meaning all countries, and “complete” all armaments and armed forces. Presumably, general and complete disarmament will require marked change in the international system. The security dilemma will have to be overcome for good. States will only be ready to drastically or completely disarm if a central authority, say, a democratised UN, will be potent enough to effectively deal with potential aggressors.³

Until such a time, mutually agreed limitation of armaments and armed forces, that is arms control, remains one of the main ways out of the security dilemma.

The Role of Military Technology

Throughout history, new technology has contributed to the shaping of societies and the relations between countries. Particular effects have stemmed from military uses of technology – qualitative superiority was instrumental in conquering other countries and seizing colonies.

² For the texts of arms-control and disarmament agreements, see UN 2009, US Department of State 2009.

³ This may also turn out as a necessary condition for a world without nuclear weapons.

Since World War II, science and technology have taken on a new, pivotal role. Their product, the nuclear bomb, brought sweeping change. War between the big powers would result in widespread annihilation, thus avoidance became a major goal, and arms control gained significance, but only after the experience of the Cuban missile crisis (1962). Nevertheless, military efforts to escape mutual assured destruction and gain the upper hand in nuclear war continued. These efforts are marked by the introduction of the hydrogen bomb, the long-range ballistic missile, multiple independently targetable re-entry vehicles on them, cruise missiles. Nevertheless, in part because of catching up, victory in nuclear war remained impossible. However, the consequence of such innovations was a markedly increased instability. Shorter flight times and in particular the prospect that one ballistic missile could destroy several adversarial ones in their silos increased the pressure for quick launch and thus the probability of war by mistake.

In parallel to these developments in nuclear-strategic weapons, technological advances were achieved in many other military fields, often enabled by microelectronics and digital computers. Satellites for intelligence, communication and navigation, precision-guided missiles and bombs, uninhabited aircraft and battle-management software mark some of the important steps.

After the Cold War at first some reduction of military research and development was observed, however to be followed by an intensification of efforts in particular in the USA. Here, key concepts have been dominant maneuver, precision engagement, focused logistics, full dimensional protection, joint operations, full spectrum dominance. Present efforts of many armed forces are directed towards “net-centric warfare”, characterised by massive information sharing. Among the particular thrusts of the US military are: uninhabited vehicles in all media, including armed ones; ballistic missile defence; information operations; directed-energy weapons. Goals for the so-called war on terror include actions against weapons of mass destruction, locating and tracking of people and material, and the neutralization of improvised explosive devices.

Even though the rhetoric today focuses on terrorist groups and failed states, armed forces still prepare for war against much more potent adversaries, that is, industrial countries with strong, modern militaries. As a consequence, the qualitative arms race is continuing, and gaining new speed, mainly driven by the advances of information and communication technology; soon, nanotechnology and converging technologies will provide new options as well as motives for accelerating military innovation. In such innovation, the USA is the clear leader – it spends two thirds of the world-wide money for military research and development (Brzoska 2006). This fits to the declared goal of the U.S. Department of Defense “to create, demonstrate, prototype, and apply S&T [science and technology] that enables affordable and decisive military superiority to defeat any adversary on any battlefield” (DDRE 2007). However, when the USA will have introduced a new type of weapon or system, usually after some time other countries, including potential adversaries of the USA will achieve similar capabilities. The questions then become whether in this race to create and maintain superiority, or, on the part of potential opponents, to prevent too large a gap and to catch up as fast as possible, the overall security and stability of the world will gain or lose, and if the latter is likely, if something can be done to prevent that. The following sections will discuss this problem for nanotechnology – if it is going to revolutionize how we produce, live, maybe even what we are, then it has the potential for revolutionary changes in the way wars are being prepared and fought, or why they need to be prevented and how this can be done.

Potential Military Uses of Nanotechnology

Because nanotechnologies span an extremely wide area, armed forces could use them in a multitude of applications and in all fields of waging, organizing and preparing war. Most applications are still at the research and technology-development stages – the main current use

of nanotechnology is in recent computer chips with structure sizes below 100 nanometers. Some applications are rather generic while others are specific for the military.⁴

Generic applications

In *electronics, information and communication technology* microelectronic components will further decrease in size, soon necessitating new principles for switching and storage, such as magnetic nanostructures, nanotubes, or molecules. Photonic devices with nanostructures will lead to faster optical data processing and transmission. Organic light-emitting diodes will allow flexible, small displays. Using such components, computers and communication devices will shrink markedly while providing much higher performance. Centimeter- or even millimeter-size computers will be part of virtually all military equipment, including in ammunition. They will allow very small sensor systems, implants and robots. Normal-size computers will provide accordingly higher processing power, to be used in battle management and logistics and in much more detailed modeling of weapons phenomena. Goals for parallel software development include human-like reasoning, communication in natural language, and autonomous decisions on many levels.

In the area of *materials*, nanoparticle and nanotube additives can make composites more flame-resistant or electrically conducting. Carbon nanotubes, extremely strong but light-weight, promise composite materials that would greatly reduce the weight of land vehicles, air- and spacecraft. In engines, nanostructured coatings can lead to less friction and wear while tolerating higher temperatures. Functional materials will become possible with integrated sensors, cables and actuators or with a self-healing capability.

Concerning *energy sources and storage*, nanostructuring of components can enable fuel cells for routine use. Nanostructures could also become essential for hydrogen storage. Organic nanocomposites could make solar cells flexible and light-weight.

In *propulsion*, materials and coatings enduring higher temperatures would increase the efficiency of engines. Nanotechnology together with microsystems technology could lead to very small rotating engines. Molecules that can contract similarly to muscles could be used for large and small walking robots.

Vehicles made of nanotechnology-based materials will have less weight which is most important for aircraft, missiles, rockets and satellites. Land vehicles and ships may profit from efficient fuel cells and better energy storage, enabling electric propulsion.

For *propellants and explosives*, nanoparticle preparations of fuel and oxidizer can show increased burn or detonation rate, maybe also higher energy density.

Specifically military applications

Flexible *camouflage*, which adapts to the background (as seen from one direction) could be achieved by nanoparticles with differently colored sides by changing their orientation. By tailoring nanostructured materials, the absorption of light or radio frequencies could be increased to achieve stealth.

With nanotechnology, *small sensors* will become possible which are highly sensitive for physical quantities such as temperature, sound, light, or for chemical or biological agents. Sensor systems with processing electronics, radio link and power supplies could be scattered on the battlefield or beyond, communicating as a wireless network.

⁴ For detailed descriptions and references see Altmann 2006: Ch. 4. Short overviews from a US perspective are given in Roco and Bainbridge 2001: Ch. 2; Roco and Bainbridge 2003: Section E; DDRE 2007a. A recent presentation is Schilthuis/Simonis 2009.

Concerning *protection* against projectiles and armor-piercing munitions, nanotechnology will probably not bring change in heavy armor – thick metal will continue to be most effective. In light armor, however, nanofiber composites may bring considerable improvement, in particular for bullet-proof garments.

In the areas of *conventional weapons*, nanomaterials will bring weight reduction. Using nanofiber composites metal-free firearms and munitions may become possible. Guidance systems could become so tiny that even small munitions could carry them. Kinetic-energy armor-piercing projectiles could get improved penetration capability by nanocrystalline tungsten. With nano-enhanced propellants and materials, smaller missiles of higher speed can become possible. Using much more precise targeting, substantially smaller explosive payload can be used – for example 100 instead of 1000 kg for surface-to-surface missiles or 5 instead of 50 kg for anti-air ones, allowing drastic decreases in missile size, weight and cost.

So-called *soldier systems* based on nanotechnology could include sensors for body status (temperature, heart rate, transpiration, stress indicators in exhaled breath). Microneedles in the skin could allow analysis of body fluids and injection of drugs. Cooling or heating could be provided by active systems. Muscle-like contraction could be used to apply wound-healing agents, to form compresses or splints. Carrying of heavy loads could be supported by an exoskeleton.

In the area of *implants* and other *body manipulation*, nanotechnology will bring qualitatively new possibilities. Sensors in soldiers' bodies could monitor the blood chemistry to quickly sense effects of stress, injury, chemical or biological agents. Implants could administer drugs or hormones for therapy or to influence the mood. The biochemical processes in cells could be altered to achieve stasis (in case of severe injury), or to permit longer periods of activity without nutrition or without sleep. Micro-electrodes contacting nerve cells could sense or influence the activity of the latter. In such a way, actions could be initiated somewhat faster, senses could be enhanced (for example, "seeing" infrared light, "feeling" radioactivity), and information could be exchanged between an implanted computer and the brain.

For *uninhabited vehicles* (or robots), nanotechnology will bring considerable advance. Such vehicles in all media (ground, water, air, outer space) will profit from improved sensors, actuators, materials, energy storage and conversion. Advances in computers will be particularly relevant for autonomy – for the assessment of complex situations and appropriate actions. Without pilots, uninhabited combat aircraft could fly narrower curves and shoot faster. If tanks and combat aircraft are to carry traditional munitions and other loads, scaling them down is limited. However, with loads or weapons of very small size and weight, new kinds of vehicles can become possible with sizes of centimeters or even millimeters. Some may be designed for crawling with insect-like legs, others with flapping wings. With *bio-technical hybrids*, implanting control electronics into insects or small mammals, several problems could be circumvented which fully artificial bodies may cause. *Micro-robots* of various types could carry sensors for reconnaissance or for detecting chemical or biological agents, could act as communication relays or as target beacons. Even if actuation is possible only on a small-scale, micro-robots could function as weapons if they hit a central node – for example, cut a wire or explode a small charge after having entered a military system covertly. Acting as a swarm, micro-robots could block air intakes or release abrasive materials. Attack against humans would be possible by impact, a small explosive charge or a toxic substance. In outer space, *small satellites* could act as anti-satellite weapon, either by kinetic impact or by rendezvous, docking and some form of manipulation.

Not much change will occur with *nuclear weapons*: they will continue to have masses of several tens to several hundreds of kilograms, necessitating large and heavy carrier systems. Improvements in guidance and control systems are possible.

For *chemical or biological weapons*, nanotechnology will open up many new options. It is a tool in pharmaceutical research for elucidating mechanisms of toxicity, illness or pain, and for designing therapeutic drugs that bind to specific sites in specific organs. Nanoparticles can encapsulate agents and, after injection or inhalation, can ferry them into cells or through the blood-brain barrier. All knowledge and technology gained could also be used for weapons. For example, mechanisms for reaction with specific gene patterns or proteins could greatly enhance the selectivity, significantly reducing the risk of infecting one's own forces or population. Ultimately, an agent is conceivable that kills or incapacitates one single individual only, remaining inactive in all other people. On the other hand, nanotechnology will provide new possibilities for *chemical or biological protection*: more sensitive, smaller and cheaper sensors, better filters and agents for decontamination after an attack.

Some of these applications could be achieved without nanotechnology. However, nanotechnology will strongly expand the capabilities of analysis and manipulation at the molecular scale, and will lead to new options for materials, sensing, and processing. Of the applications mentioned, only few will become available in the coming five years; most would need ten or even twenty years to arrive. In a few cases (explosives, heavy armor, armor piercing, nuclear weapons) nanotechnology will bring modest improvement. In many more, significant advancement is expected. Radical or revolutionary change can be foreseen in the generic areas of electronics, computers, materials, and perhaps software, and in the military-specific applications of soldier systems, body manipulation, large and small uninhabited vehicles, small satellites and chemical/biological weapons.

Many of these areas will be characterized by dual-use technologies with close links between military and civilian uses. This is obvious for the generic applications, but holds also for implants, robots, satellites, and pharmaceutical/biotechnological uses of nanotechnology. Not all research efforts will lead to deployed military systems. For example, small systems could turn out too limited in mobility, energy supply, communication capability or payload.

Military Research and Development of Nanotechnology

Several countries have taken up military work in nanotechnology, but the US is by far the most active. Since the beginning of the US National Nanotechnology Initiative (NNI), the Department of Defense has received one quarter to one third of the NNI funds, in 2008 \$460 million out of \$1,554 million. Figure 1 shows the respective expenses and the military share.

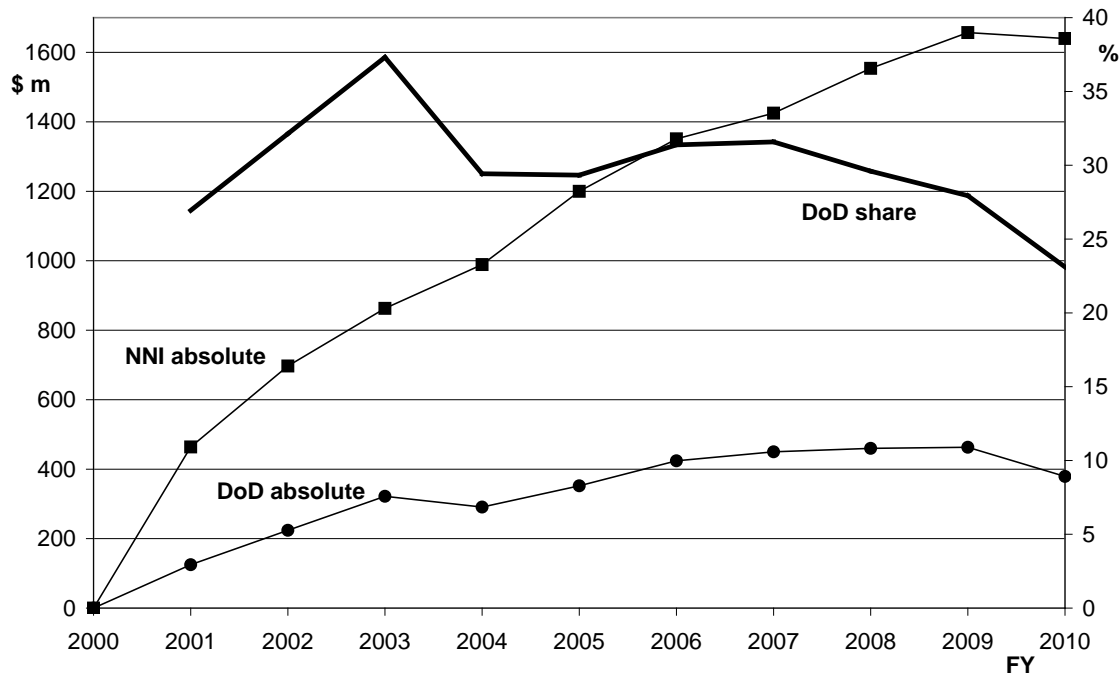


Fig. 1 Funding in the US National Nanotechnology Initiative (NNI) for the Department of Defense (DoD) and NNI total (in \$ million, left scale), and DoD share (in per cent, right scale) in the Fiscal Years (FY) since the beginning of the NNI. (2001-2008 actual, 2009 estimate, 2010 proposed; Sargent 2009, NNI 2009.)

Other countries spend much less on military nanotechnology although Europe and Japan are on a par with the US in total spending for nanotechnology.

In each of the seven Program Component Areas of the NNI, the Department of Defense has defined its own Program Goals. For example, in *Fundamental Nanoscale Phenomena and Processes*: “To discover new phenomena and processes to enable breakthrough advantages for war fighter and battle systems capabilities;” in *Nanomaterials*: “To harness biological and biologically inspired processes for low-cost synthesis and templating of designed nanostructures”; in *Societal Dimensions*: “To enable physicochemical characterization and toxicology for water, air and space environments” (DDRE 2007a).

More concrete while farther-reaching ideas for military applications had been given at the first NNI conference on converging technologies (National Security 2003):

1. Data linkage, threat anticipation, and readiness (miniature sensors, high-speed processing, wide-bandwidth communication),
2. Uninhabited combat vehicles (no-pilot aircraft with artificial brain emulating a skilful pilot, similar for tanks, submarines, etc.),
3. Warfighter education and training (virtual-reality teaching, computer interaction including speech),
4. Chemical/biological/radiological/explosive (CBRE) detection and protection (micro sensors, protective masks/clothing, decontamination/ neutralisation),
5. Warfighter systems (increased information/connectivity, prolific unattended sensors and uninhabited, automated surveillance vehicles, physiological monitors for alertness, chemical/biological threats, casualty assessment, low volume/weight/power burdens),
6. Non-drug treatments for enhancement of human performance (possibly modify human biochemistry to compensate for sleep deprivation, enhance survivability from physical injury),

7. Applications of brain-machine interface (take brain signals non-intrusively, control actions and impart back feedback signals).

Nearly all of the Defense nanotechnology funding goes into research and technology development (e.g. DDRE 2007a), system development that would bring about something that could be deployed with the armed forces is not yet relevant. Many projects are done at universities and in the laboratories of the services Army, Navy and Air Force. Three of the about 40 research centers of the National Nanotechnology Initiative belong to the Department of Defense (NNI 2009a). One has been founded at the Massachusetts Institute of Technology, the Institute for Soldier Nanotechnologies, funded by the Army since 2002 with \$10 million per year. The “ultimate goal” is “a 21st century battle suit ... a bullet-resistant jumpsuit, no thicker than ordinary spandex, that monitors health, eases injuries, communicates automatically, and reacts instantly to chemical and biological agents.” (ISN 2009) Among the capabilities aimed for are communication and data processing capabilities, cooling or heating, monitoring of body functions, forming of wound compresses and splints around fractures, and administering of drugs. These goals are pursued by over 170 people, organized in 5 strategic research areas comprising 31 projects (ISN 2009a, 2009b). The Naval Research Laboratory founded the Institute for Nanoscience in 2001. This NNI center does “multidisciplinary research at the intersections of the fields of materials, electronics and biology”, with projects in nanoassembly, nano-optics, nanochemistry, nanoelectronics and nanomechanics (NRL 2009, 2009a). University research, often funded by the Defense Advanced Research Projects Agency, is very broad; examples range from a Hyper-Uniform Nanophotonic Technology Center (Kloepffel 2004) via strong fibers from carbon nanotubes (Dalton et al. 2004) to the implantation of control electronics into pupae for controlling the flight of the insect after metamorphosis (Bozkurt et al. 2009).

Other countries are active in military research and development of nanotechnology, too, but at significantly lower expenditures than the US ones (civilian spending is different, total government funding for nanotechnology is about equal in the USA, Europe and Japan). Available information indicates that Great Britain, Netherlands and Sweden spend on the order of several millions of dollars or euros per year.⁵ For France and Israel, probably the same holds. There is no information on the expenditures in Russia and China, but they are certainly far below the US ones. My cautious estimate remains that the US spends 80-90 % of the world total in military nanotechnology research and development, that is four to ten times as much as the rest of the world. It should be noted that the US share in military research and development in general is “only” around two thirds (Brzoska 2006). If US efforts in military nanotechnology will continue at the present pace, other countries will certainly ramp up their respective spending. China and Russia have strong nanotechnology programs and world-class research. Both countries would be able to develop and deploy nanotechnology-based military systems not too long after the USA would have done so. Further countries have started military work, for example Iran (RedOrbit 2005); the common Indo-Brazil-South Africa Nanotechnology Initiative includes cooperation in defense (Raj 2008: 128).

Doubtful hopes for and secrecy about military programs contribute to exaggerated fears and begin to fuel an arms race in nanotechnology research and development. Former Prime Minister Peres of Israel spoke of soldierless war and invisible weapons (Malsch 2004). Indian President Kalam called on scientists and engineers to create nano-vehicles, -explosives and -robots (Kalam 2004). An article relating a US study to a military audience in China was misrepresented in the USA as showing Chinese plans for ‘ant robots’ against the USA (Altmann/Gubrud 2004).

Preventive Arms Control – the Concept

⁵ Based on public information for the UK (UK MoD 2001, 2009) and Sweden (Perez/Sandgren 2008: App. D), and oral information for the Netherlands (2007).

New military technologies can bring strong dangers – as demonstrated in the Cold War with the destabilization that followed after each major qualitative step in the nuclear arms race (ballistic missiles, multiple warheads, precise targeting). Such dangers were contained insufficiently and too late, limits were often agreed upon long after deployment, and zero was not often achieved. The INF Treaty of 1987 with the complete abolition by the USA and the Soviet Union of their intermediate-range nuclear missiles and the START I Treaty of 1991 with removal of multiple warheads represent notable exceptions. Today many would agree that it would have been better for stability and world peace if destabilizing new kinds of weapons would have been prohibited from the beginning instead of building them up and then limiting their numbers. This is the idea of preventive arms control.

In a simplified linear model of a new military technology, weapon or weapon system, at the start there is *research* which provides a general idea and some outlook on feasibility. The next stage is *development*, often of a prototype, which then undergoes *testing*. If the result is deemed suitable, *deployment* of the new systems will follow, after which comes *use* and, from time to time, *modernization*, and finally, maybe after several decades, *taking out of service*. Arms control is preventive, if it acts before the stage of deployment. Treaties can just ban deployment or can include the earlier stages of testing or development. Research proper is difficult to limit because its results mostly cannot be predicted and because knowledge gained by research can be used for very different types of application. However, a legal ban on one stage can have indirect effects on earlier stages – if deployment is prohibited, then one could save money by not continuing development and testing. On the other hand, if there is a strong military interest, then a deployment ban may be insufficient – systems could be developed to ready status and production prepared in secret for a surprising treaty breakout so that the partners could not react in time. To prevent such a scenario, it is best to agree on a comprehensive prohibition which includes testing and development.

There are several precedents of preventive arms control. The Partial Test Ban Treaty of 1963 and the Comprehensive Test Ban Treaty of 1996 are directly aimed at testing (and, indirectly, have even stopped certain types of research, namely experimentally studying effects of nuclear explosions). The Non-Proliferation Treaty of 1968 is preventive for the non-nuclear weapon states: they must not manufacture or acquire nuclear weapons. The Anti-Ballistic Missile (ABM) Treaty of 1972 (terminated 2002) prohibited among others development, testing and deployment of sea-, air- and space-based ABM systems which did not exist at the time of signing. Both, the Biological Weapons Convention of 1972 and the Chemical Weapons Convention of 1993, ban not only production and use, but also development of the respective weapons. In international humanitarian law, there is a general rule that countries have to check whether a new weapon, means or method of warfare would be prohibited (Art. 36, Geneva Protocol I of 1977). Laser weapons for permanently blinding people were prohibited by a Protocol in 1995 before they had been fully developed.⁶

Preventive arms control was introduced in the Cold War, but continues to be relevant after it. Technology is developing fast while the fundamental problems of threats, security dilemma and arms race still exist. Even though there is much talk about the new shape of war – asymmetric, against insurgents, in failing states – armed forces still prepare for the contingency of large-scale war between countries. Thus, also in present times countries can improve their respective security by reciprocal limits on dangerous new military technologies. Many high technologies and high-technology systems cannot be developed in covert, small-scale facilities, so if states will not work on these, in parallel they will prevent terrorists from getting them.

⁶ In this case the legal prohibition only concerns use, but development and testing of such laser weapons were terminated in all relevant countries.

Preventive arms control has to be prepared by interdisciplinary research. The first step is scientific-technical analysis of the respective technology/system – what would be the properties of the technology or weapon, how would the effect propagate, what would be the outcome on a target? Second, the military-operational aspects have to be studied – what would be likely targets, in what scenarios? What collateral effects are possible? Third, the results have to be assessed under certain criteria. If the conclusion is that limits are advisable, then, fourth, options for such limits and methods of verification of compliance have to be considered. Here, also the positive uses that should not be overly restricted, and the effort and intrusiveness of verification have to be factored in. Ideally, then, the relevant countries would take up the findings and start negotiating.

The criteria of preventive arms control can be put in three groups (Altmann, 2005, Ch. 4, 2006, Ch. 5):

I. Adherence to and further development of effective arms control, disarmament and international law

1. Prevent dangers to existing or intended arms-control and disarmament treaties
2. Observe existing norms of humanitarian law
3. No utility for weapons of mass destruction

II. Maintain and improve stability

1. Prevent destabilization of the military situation
2. Prevent technological arms race
3. Prevent horizontal or vertical proliferation/diffusion of military-relevant technologies, substances or knowledge

III. Protect humans, environment and society

1. Prevent dangers to humans
2. Prevent dangers to the environment and sustainable development
3. Prevent dangers to the development of societal and political systems
4. Prevent dangers to the societal infrastructure.

Groups I and II are about the prevention of armed conflict or how it is waged. Group III concerns dangers arising in peacetime – for example, by new pollutants, or by systems which could proliferate to terrorists.

Preventive Arms Control Applied to Military Uses of Nanotechnology

In the assessment of 21 potential military applications of nanotechnology under the criteria of preventive arms control, the generic applications have turned out to be not very dangerous or too close to civilian uses so that limitations would be plainly impractical. Of the specific applications, one category – improved sensors for biological or chemical warfare agents – got a positive rating because such sensors could improve verification of compliance with the respective Conventions or would allow better warning of terrorist attacks. Several applications, however, would bring serious dangers, Table 1 shows a simplified overview (Altmann 2006: Ch. 6).

Table 1. The most dangerous potential military applications of nanotechnology with the affected group of preventive-arms-control criteria

Area of concern	Arms control / International Humanitarian law / Weapons of mass destruction	Military stability / Arms race / Proliferation	Humans / Environment / Society / Infrastructure
Potential Application			
Distributed small sensors		X	X
Metal-free firearms		X	X
Small missiles		X	X
Implants and other body manipulation		X	X
Autonomous combat systems	X	X	
Small robots	X	X	X
Small satellites and launchers	X	X	
New chemical/biological weapons	X	X	X

In developing recommendations for international action to preventively prohibit or limit these applications, general guidelines were used, leading to the following general conclusions:

- Nanotechnology has many positive uses, so its complete prohibition (including in the civilian sector) would be counterproductive and impractical.
- A hypothetical prohibition of using nanotechnology in the military would lead to difficult definition problems and a requirement of very intrusive verification – up to the analysis of materials and control electronics at the nanometer scale, which would certainly not be acceptable for armed forces.

For both reasons, limits should not be tied to nanotechnology, but to the respective military systems or missions. Concerning small and very small systems, a prohibition should start at a macroscopic size so that verification can rely mostly on visual inspection from the outside without special magnifying equipment mostly. In order to prevent circumvention by civilian systems which could be modified easily for military purposes, civilian uses have to be included into the regulation. To prevent fast breakout, prohibitions should not only hold for use and deployment, but also for the earlier stages of testing and development. Preventive limitation should focus mostly on the new, future applications; attempting to include weapons or systems which are already widely introduced may lead to too strong political or military resistance. Their reduction and disarmament should be left to later, different negotiations. Nevertheless, preventive arms control should be integrated in the general process of arms control and disarmament.

Following these lines of reasoning, the most important recommendations are (Altmann 2006: Ch. 7):

- Ban on self-contained sensor systems below a certain size limit (3 to 5 cm), for the military and civilian sectors.
- Ban on small arms, light weapons and munitions that contain no metal, for the military and civilian sector.
- Ban on missiles below a certain size limit (0.2-0.5 m), for the military and civilian sector.
- Moratorium on body implants and other body manipulation that are not directly medically motivated, for the civilian and military sectors.

- Prohibition of armed, uninhabited vehicles of normal size, with numerical limits on unarmed vehicles (exempting the already existing ballistic and cruise missiles).
- Prohibition of small, uninhabited vehicles below a certain size limit (0.2-0.5 m) in the military and civilian sectors.
- Ban on space weapons of all kinds – this would include nanotechnology-enabled small satellites used as weapons. Small satellites and launchers for other uses should be subject to regulation, notification and inspection.
- The Chemical Weapons Convention and the Biological Weapons Convention should be upheld, the latter should be augmented by a Compliance and Verification Protocol.

All these prohibitions and limits should start at the development stage. For some of the rules, exceptions should be agreed upon for important civilian or military positive uses. For example, with respect to small missiles, firecrackers and life-saving apparatus for stranded ships should be exempted from the ban. Concerning small unarmed vehicles, a limited number may be allowed per country for investigating shattered buildings. However, here additional precautions would be needed against simple modification and use for military purposes, such as restrictions on power supply and on remote-control range.

The proposed ban on armed, uninhabited vehicles would mean withdrawal of a few types of uninhabited aerial vehicles (UAVs) in particular by the USA which since several years uses missile-carrying UAVs (Predator and Reaper) for attacks in Iraq, Afghanistan and Pakistan (with considerable numbers of civilian casualties, Weber 2009). Following the US precedent, also other countries strive for arming their UAVs. If these developments cannot be stopped, then at least a human should be involved in each decision on targeting and weapon release – autonomous firing by machine should be prohibited (Sharkey 2008, Altmann 2009), and limitations concerning range and deployment in threatening postures should be introduced (Sparrow 2009).

To be workable, definitions, details of exceptions and precautions as well as verification methods and means need to be worked out in detail, similar to the definitions in Art. II of the Chemical Weapons Convention or in the Definitions Annex of the Strategic Arms Reduction Treaty of 1991, and the respective inspection/verification annexes and protocols (see UN 2009, US Department of State 2009).

Pivotal Role of the USA

Nanotechnology and converging technologies pose a fundamental problem. How should humankind deal with revolutionary technology on the international level?

One approach is found in the following quotes from the first US workshop on converging technologies, held in connection with the National Nanotechnology Initiative: ‘... reduce the likelihood of war by providing an overwhelming U.S. technological advantage...’, ‘... it is essential to be technologically as far ahead of potential opponents as possible.’ (National Security 2003) This is in line with the general goal of US military research and engineering quoted in Section 5, namely “decisive military superiority to defeat any adversary on any battlefield” (DDRE 2007a). There is some immanent logic here, however, this approach overlooks the interactions in the international system, in particular the dangers to the USA which are likely to ensue when potential opponents will command similar technology and systems. As explained in Section 5, a US monopoly or lead in nanotechnology-based military applications is not likely to last long. Adversaries could use them against the USA, also asymmetrically. Some nanotechnology-based weaponry, once developed by state-sponsored military research and development, could find its way into the hands of terrorists. This holds mainly for smaller systems that do not need big infrastructure or logistics, but with the foreseeable advances in autonomous control they could wreak havoc nevertheless.

A sober analysis of the potential dangers, proceeding from a long-term view of national security, should lead the USA (and other technologically leading countries) to the understanding that restraint and international limits are in their enlightened national interest. Because the USA is spending by far the most money for military research and development of nanotechnology, it acts as a precedent and role model for many other countries. Restraint on the part of the USA and the readiness to discuss about mutual preventive limitations would reduce pressures to catch up. With its focus on multilateral policy and the ambition to work towards nuclear disarmament, the new US administration provides some reason for hope in this matter.

Long-term Future of the International System

If the countries active in military high technology agree to negotiate about containing the most dangerous military applications of nanotechnology, they could agree on prohibitions and limits as proposed here. Verification of compliance could to a large extent be carried out by traditional methods of on-site inspection, in some cases augmented by sample-taking and analysis and by magnifying equipment. This could work for the coming 1-2 decades. However, with the further development, nanotechnology and converging technologies will become more wide-spread, many systems and production units will shrink in size and become cheaper. Increasingly, processes and products will be dual use – that is, could serve for civilian as well as military purposes. Individuals and small groups will be able to afford table-top microreactors and DNA synthesizers that could be used to make new biochemical agents for which antidotes do not yet exist. Service robots could be re-programmed, and fitted with weapons. Militarily relevant technology and systems could be developed in small, innocuous-looking buildings. As a consequence, also small countries and even non-state actors will be able to use nanotechnology for destructive purposes. This means that to remain effective beyond ten or twenty years, international preventive arms control has to involve nearly all countries, and verification of compliance has to be very intrusive, essentially with the right to anywhere and anytime, short-notice on-site inspections. Whereas such inspections are accepted if done by one's own government institutions – for example in the context of crime prevention, workplace safety or environmental protection –, granting far-reaching inspection rights of military installations to foreigners will likely meet strong resistance. This is because such inspections endanger military secrecy. Secrecy is one precondition of victory in war, because the more an adversary knows about one's armed forces – technical specifications, strategies, dislocation plans, troop morale etc. – the better are his chances for successful attack, in particular surprise attack exploiting weak points.

So in two or three decades the question may emerge whether the established mechanisms to provide international security in the presence of national armed forces and the security dilemma, namely adequately verified arms control, will still be able to work. This means nothing less than the question whether the international system as we know it can be kept stable with the coming revolutionary technologies.

Verification of limits on nuclear arms and their proliferation was relatively easy: special materials and very large installations are required for their production, carriers and their infrastructure can be seen from satellites. For limits on tanks, artillery and aircraft, on-site inspections of military installations are required. Whereas on-site inspections with sample analysis are part of the Chemical Weapons Convention, efforts to add similar mechanisms to the Biological Weapons Convention faltered in 2001, mainly due to concerns about secrecy in military as well as pharmaceutical research (Nixdorff et al. 2003: Ch. 8). Future nanotechnology and converging technologies will demand markedly more intrusive verification: one has to consider millions of potential actors, easily available materials, and extremely small and extremely numerous weapons.

If such intense verification will prove unattainable, then either the revolutionary technologies will bring unprecedented dangers. The situation will be characterized by increasing military and terrorist threats and drastic instability. Imagine:

- micro-robots covertly deployed inside military systems of a potential adversary, ready to strike any time,
- very small satellites shadowing important civilian and military satellites, attacking without prior notice,
- assassinations of politicians by small, target-seeking missiles pulled out from lady's handbags,
- flies as carriers of espionage equipment, mosquitoes injecting lethal poisons, or
- “molecular hackers” synthesizing and distributing unknown infectious agents which kill generally or selectively.

The alternative is fundamental change in the international system, organizing global security in another way: not by the threat of national armed forces, but by a monopoly of legitimate violence resting with a (democratised) United Nations Organisation and an international criminal law with the right to act within states – organising global security essentially in the same way as citizen's security is provided for within countries. This means voluntary reductions of state sovereignty, establishing an international authority with a monopoly of force while decreasing the dependence on national armed forces. Getting there obviously will mean a long and tedious process, but first trends in this direction already exist – there is the UN Charter, the European Union sets a precedent, and international courts of justice assume increasing importance.

An ethical approach to war and peace should promote all steps in this direction. Insofar as nanotechnology and converging technologies will likely make the ethical imperative of preventing war by a fundamental solution much more urgent, one can argue that there is a specific new aspect, so that these considerations form part of nano-ethics.

Conclusions

ELSA Research

There is much research of ethical, legal and societal aspects of nanotechnology. Unfortunately, however, military uses of nanotechnology and their potential consequences for international security are investigated only very rarely. Given the importance for the future of humankind, this needs to be corrected. Research in ethical, legal and societal aspects should explicitly include the intentional destructive uses of nanotechnology. There is an urgent need to follow up military R&D of NT in various countries, not the least to avoid arms races fuelled by insufficient information and worst-case assumptions about capabilities of potential opponents. Also, preventive-arms-control measures and verification methods need to be investigated in more detail. For the USA, “Goal 4: Support responsible development of nanotechnology” of the NNI Strategic Plan proposes various ideas for research of societal developments, such as scenario analysis, multiagent modeling and comparison with the histories of other technologies (NNI 2007). Some of these ideas could be transferred to the transnational level and applied to international security.

International Security and Nano-Ethics

Countries should include military applications into their ‘International Dialogue on Responsible Research and Development of Nanotechnology’ (European Commission, 2008). If this meets administrative problems, then a special forum on nanotechnology and international security should be set up.

An ethical approach to military uses of nanotechnology should give the highest priority to avoiding large-scale war, with appropriate preventive limitations of the most dangerous applications. Given sufficient political will, preventive arms control among the countries active in

military high technology will be able to contain such dangers, using traditional verification methods, for one to two decades. Maintaining international security in the long run, however, may require fundamental change in the international system. Deepening the understanding of the need, the process and the forces should become part of nano-ethics.

References

- Altmann, Jürgen (2005) *Nanotechnology and Preventive Arms Control*, Forschung DSF No. 3, Osnabrück: Deutsche Stiftung Friedensforschung, <http://www.bundesstiftung-friedensforschung.de/pdf-docs/berichtaltmann.pdf> (1 Oct. 2009).
- Altmann, Jürgen (2006) *Military Nanotechnology: Potential Applications and Preventive Arms Control*, Abingdon/New York: Routledge.
- Altmann, Jürgen (2009) Preventive Arms Control for Uninhabited Military Vehicles, in Capurro, Rafael, Nagenborg, Michael (eds.) *Ethics and Robotics*, Heidelberg: AKA.
- Altmann, J., Gubrud, M. (2004) Anticipating Military Nanotechnology, *IEEE Technology and Society Magazine*, 23 (4) 33-40.
- Bozkurt, Alper (2009) Insect–Machine Interface Based Neurocybernetics, *IEEE Transactions on Biomedical Engineering*, 56 (6) 1727-1733.
- Brzoska, Michael (2006) Trends in Global Military and Civilian Research and Development and their Changing Interface, *Proceedings of the International Seminar on Defence Finance and Economics*, New Delhi, 13-15 November 2006, pp. 289-302, www.ifsh.de/pdf/aktuelles/india_brzoska.pdf (1 Oct. 2009).
- Bugnion, Francois (2002) Just wars, wars of aggression and international humanitarian law, *International Review of the Red Cross*, 84 (847) 523-546, English version at [http://icrc.org/Web/Eng/siteeng0.nsf/htmlall/5FLCT4/\\$File/bugnion%20ang%20.pdf](http://icrc.org/Web/Eng/siteeng0.nsf/htmlall/5FLCT4/$File/bugnion%20ang%20.pdf) (6 Aug. 2009).
- Bull, Hedley (1961) *The Control of the Arms Race: Disarmament and Arms Control in the Missile Age*, London: Weidenfeld & Nicolson for the Institute for Strategic Studies.
- Dalton, Alan B. et al. (2004) Continuous carbon nanotube composite fibers: properties, potential applications, and problems, *Journal of Materials Chemistry* 14 (1) 1-3.
- DDRE (Director, Defense Research and Engineering) (2007) *2007 Department of Defense Research & Engineering Strategic Plan*, Washington DC: Department of Defense, http://www.dod.mil/ddre/doc/Strategic_Plan_Final.pdf (1 Oct. 2009).
- DDRE (Director, Defense Research and Engineering) (2007a) *Defense Nanotechnology Research and Development Programs*, Washington DC: Department of Defense, <http://www.nano.gov/html/res/pdf/DefenseNano2007.pdf> (7 Aug. 2008).
- Drexler K. Eric (1981) Molecular engineering: An approach to the development of general capabilities for molecular manipulation, *Proceedings of the National Academy of Sciences* 78 (9) 5275-5278.
- Drexler K. Eric (1986/1990) *Engines of Creation – The Coming Era of Nanotechnology*, New York: Anchor/Doubleday.
- European Commission (2008) *International Dialogue – Towards a global co-operation in nanotechnology*, <http://cordis.europa.eu/nanotechnology/src/intldialogue.htm> (7 Oct. 2009).

Fleck, Dieter (2008) *The Handbook of International Humanitarian Law* (2nd ed.), Oxford: Oxford University Press.

Goldblat, Jozef (2002) *Arms Control – The New Guide to Negotiations and Agreements*, 2nd ed., London: Sage.

Gubrud Mark A. (1997) *Nanotechnology and International Security*, paper presented at 5th Foresight Conference on Molecular Nanotechnology, <http://www.foresight.org/Conferences/MNT05/Papers/Gubrud> (8 Oct. 2009).

ICRC (International Committee of the Red Cross) (2009) *International Humanitarian Law*, <http://www.icrc.org/web/eng/siteeng0.nsf/htmlall/ihl?OpenDocument> (7 Aug. 2009).

ISN (Institute for Soldier Nanotechnologies) (2009) *About ISN*, <http://web.mit.edu/isn/aboutisn/index.html> (8 Oct. 2009).

ISN (Institute for Soldier Nanotechnologies) (2009a) *People*, <http://web.mit.edu/isn/people/index.html> (8 Oct. 2009).

ISN (Institute for Soldier Nanotechnologies) (2009b) *Research*, <http://web.mit.edu/isn/research/index.html> (8 Oct. 2009).

Jervis, Robert (1978) *Cooperation Under the Security Dilemma*, *World Politics*, 30, 167-214.

Kalam, Abdul (2004) *Speech at a celebration of the Weapons and Electronic Systems Engineering Establishment (WESEE) of the Indian Navy*, *The Hindu*, 1 July 2004.

Kloeppel, James E. (2004) *DARPA funds new photonic research center at Illinois*, <http://news.illinois.edu/news/04/0621hunt.html> (12 Oct. 2009).

Kosal, Margaret (2009) *Nanotechnology for Chemical and Biological Defense*, Berlin etc.: Springer.

Malsch, Ineke (2004) *Shimon Peres dreams of a nanowar*, <http://www.nanoforum.org>, news, 16 April 2004 (26 April 2004).

Moseley, Alexander (2009) *Just War Theory*, *The Internet Encyclopedia of Philosophy*, <http://www.iep.utm.edu/jjustwar.htm> (6 Aug. 2009).

National Security Goals for NBIC (2003), Section E, in: Roco, Mihail C., Bainbridge, William S. (eds.) *Converging Technologies for Improving Human Performance – Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, Boston etc.: Kluwer, 2003, also http://www.wtec.org/ConvergingTechnologies/1/NBIC_report.pdf (7 Oct. 2009).

Nixdorff Kathryn, Hotz Mark, Schilling Dagmar, Dando Malcolm (2003) *Biotechnology and the Biological Weapon Convention*, Münster: agenda.

NNI (The National Nanotechnology Initiative) (2007), *Strategic Plan*, December 2007, http://www.nano.gov/NNI_Strategic_Plan_2007.pdf (8 Oct. 2009).

NNI (The National Nanotechnology Initiative) (2009), *Supplement to the President's FY 2010 Budget*, Executive Office of the President, May 2009, http://nano.gov/NNI_2010_budget_supplement.pdf (2 Aug. 2009).

NNI (The National Nanotechnology Initiative) (2009) NNI Centers, Networks and Facilities, <http://www.nano.gov/html/centers/nnicenters.html> (8 Oct. 2009).

NRL (Naval Research Laboratory) (2009) Nanoscience Institute, <http://www.nrl.navy.mil/content.php?P=MULTIDISCIPLINE> (12 Oct. 2009).

NRL (Naval Research Laboratory) (2009a) Current Topics in the Nanoscience Task Area, <http://www.nrl.navy.mil/nanoscience/programs.html> (12 Oct. 2009).

Perez, Eugenia, Sandgren, Patrik (2008) *Nanotechnology in Sweden – an Innovation System Approach to an Emerging Area*, VA 2008:03, Stockholm: Vinnova Analysis, www.vinnova.se/upload/EPiStorePDF/va-08-03.pdf (12 Oct. 2009).

Orend, Brian (2005) Just War Theory, Stanford Encyclopedia of Philosophy, <http://plato.stanford.edu/entries/war/#2> (6 Aug. 2009).

Raj, Baldev (2008) Indo-Brazil-South Africa Nanotechnology Initiative – A Case Study of Effective Cooperation, in Tomellini, Renzo, Giordani, Julien (eds.), *Third International Dialogue on Responsible Research and Development of Nanotechnology*, Brussels, 11-12 March, ftp://ftp.cordis.europa.eu/pub/nanotechnology/docs/report_3006.pdf, 20 June 2009.

RedOrbit (2005) Biography of Iranian Defence Minister Brig-Gen Mostafa Mohammad Najjar, 7 November 2005, http://www.redorbit.com/news/international/297326/biography_of_iranian_defence_minister_brig_gen_mostafa_mohammad_najjar/index.html (9 Oct. 2009).

Roco, Mihail C., Bainbridge, William S. (eds.) (2001) *Societal Implications of Nanoscience and Nanotechnology*, Boston etc.: Kluwer, also <http://www.wtec.org/loyola/nano/NSET.Societal.Implications/nanosi.pdf> (7 Oct. 2009).

Roco, Mihail C., Bainbridge, William S. (eds.) (2003) *Converging Technologies for Improving Human Performance – Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, Boston etc.: Kluwer, also http://www.wtec.org/ConvergingTechnologies/1/NBIC_report.pdf (7 Oct. 2009).

Sargent, John F. (2009) *Nanotechnology: A Policy Primer*, CRS Report for Congress, Washington DC: Congressional Research Service, 7 February 2009, <http://www.fas.org/sgp/crs/misc/RL34511.pdf> (7 Oct. 2009).

Schelling, Thomas C., Halperin, Morton H. (1961) *Strategy and Arms Control*, New York: Twentieth Century Fund.

Schilthuizen, Steven, Simonis, Frank (2009) Nanotechnology – Innovation Opportunities for Tomorrow's Defence, Delft: TNO, <http://www.isoconnectors.com/defensie/> (13 Oct. 2009).

Sharkey, Noel (2008) Cassandra or False Prophet of Doom: AI Robots and War, *IEEE Intelligent Systems*, 23 (4) 14-17.

Sparrow, Robert (2009) Predators or Plowshares? Arms Control of Robotic Weapons, *IEEE Technology and Society Magazine*, 28 (1) 25-29.

UK MoD (Ministry of Defence) (2001) Nanotechnology: Its Impact on Defence and the MoD, <http://www.mod.uk/NR/rdonlyres/63E7F0AE-3BBF-4ED9-8FD8-74A733CB40F0/0/nanotech.pdf> (12 Oct. 2009).

UK MoD (Ministry of Defence) (2009) R & D Objective, Emerging Technologies: Metamaterials, Micro and Nano Technologies,
http://www.science.mod.uk/strategy/dtplan/sector_CrossCutting.aspx?Themeld=2533ce21-898c-4027-b39b-d7dc545d4617&ThemeType=rdo&ActivityId=6f92549e-e641-4747-8f14-e5bbec2c5c8a&ActivityType=rd& (12 Oct. 2009).

UN (United Nations) (2009), UNODA Treaties Database,
<http://www.un.org/disarmament/HomePage/treaty/treaties.shtml> (7 Oct. 2009).

US Department of State (2009) Treaties and Agreements,
<http://www.state.gov/t/vci/trty/index.htm> (7 Oct. 2009).

Walzer, Michael (1977) *Just and Unjust Wars – A Moral Argument with Historical Illustrations*, New York: Basic (4th ed. 2006).

Weber, Jutta (2009) Robotic Warfare, Human Rights & the Rhetorics of Ethical Machines, in Capurro, Rafael, Nagenborg, Michael (eds.) *Ethics and Robotics*, Heidelberg: AKA.

Nanotechnology, 'Curing Aging' and Finding the Bite to 'Nanoethics'

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What Should be the Task of Upstream Technology Assessment?: According to the National Highway Traffic Safety Administration data 3,070,325 people died in car wrecks in the United States during the 20th Century—approximately 31,000/year. 41,059 people died in 2007, the year for which the most recent data is available. This is bad, and many different people from public and private sectors have put a lot of effort into reducing highway fatalities. Progress has been made. The number of annual fatalities has dropped from a maximum in 1972 of 54,589, and the number of fatalities per million-vehicle-miles-traveled has dropped from 24.085 (1921—first year for which this data is available) to 1.37 in 2007. Nonetheless, it is clear that the introduction of the automobile has not been without serious risk.

Had there been an “upstream technology assessment effort” in the late 19th Century, what conclusions might have reached about the possible introduction of “automotive transport?” Suppose it had been clear to this assessment effort that there would be over three million fatalities tied to this new technology in the next Century. What conclusions would have been reached?

This brief hypothetical exposes two concerns I want to explore with upstream technology assessment. The first is epistemic: We are bad at predicting how a new technology is going to be “socially embedded.” There are many examples of wildly off-base predictions: “Energy too cheap to meter” comes to mind, as does talk of the “paperless office.” The second is ethical: It seems highly contentious to me that my hypothetical 19th Century upstream technology effort *should* have resisted the introduction automotive technology, even knowing the risks. And they didn't know the risks. Attempting a simple judgment about the introduction of such a technology seems radically at odds with the complexity of the socio-technical change underway.

Already it is clear that the epistemic and the ethical concerns interact. An ethical assessment depends on knowledge of risks, and our epistemic inabilities foreclose a neat solution. I have always found it difficult to understand how something like the “precautionary principle” would have worked in the 19th Century proto-automotive context.

So I have concerns, but I remain positively disposed toward upstream technology assessment. In part, I am positively disposed because I believe that more and better interaction between the scientists and engineers creating new technological opportunities and social scientists and humanists concerned with understanding the social and human dimensions to socio-technical developments will be good. This is almost simply an article of faith. This kind of communication will provide humanists and social scientists a deeper understanding of technological possibility, and vice versa, a deeper understanding of the human and social dimensions to emerging technologies will be afforded scientists and engineers. Better understanding all around has got to help lead to better socio-technical systems. This is my faith.

Upstream technological assessment could help avoid undesirable developments. It could help expose and avoid unjust distributions of benefits and harms with the introduction of new socio-

technical systems. It could help avoid costly changes after systemic “lock-in.” Who knows, maybe we could have had a keyboard with a better layout of keys.

I argue that we need to distinguish speculative socio-technological futures from reliable predictions of risks. Different kinds of assessment activities are needed in these different cases. Conceptual harm or a kind of absurdity results when we use the wrong kind of assessment for one or the other of these kinds of cases.

Live Long Enough to Live Forever: I want to approach the topic by looking at a particular case, research on aging. Sharply varying ethical conclusions can be found about the need for research aimed at radically increasing lifespan. By examining these points of contention, I aim to show what kind of normative or ethical work should be done with what kind of technology-in-the-making.

The title of Ray Kurzweil and Terry Grossman’s 2004 book is not hyperbole: *Fantastic Voyage: Live Long Enough to Live Forever*. The authors acknowledge that we do not *now* have

“all the techniques we need to indefinitely extend human life,” but we are acquiring these techniques, and we are doing so quickly enough that, with some attention to staying healthy, “immortality is within our grasp.” They write:

[O]ur paradigm-shift-rate—the rate of technical progress—is doubling every decade.... So ... the knowledge exists, if aggressively applied, for you to slow aging and disease processes to such a degree that you can be in good health and good spirits when the more radical life-extending and life-enhancing technologies become available... (Kurzweil and Grossman 2004, 3).

Kurzweil and Grossman see three bridges to immortality. The first bridge is to live healthy, so that one is alive when new biotechnology cures for the standard killer diseases— cancer, heart disease, others—are available. Living healthy certainly includes diet and exercise, but they take this to a significantly more intensive level. Much of *Fantastic Voyage* is about the detailed regiment of diet, vitamins and exercise that they argue will keep one alive—and Kurzweil is in his 60s—until we have cures for killer diseases. The second bridge is provided by biotech cures for these killer diseases. These cures will allow us to live even longer, long enough to arrive at the third bridge: genuine nanotechnology-artificial intelligence inspired immortality. This might come from some kind of radical transplantation—replacing aging bodies or parts of bodies with better longer-lasting bodies or parts—or from some kind of ongoing “nanobot” body upkeep.

I am not here to assess the truth of such claims. However, there is significant research on the aging process, and there are researchers who claim that we are significantly closer to understanding the underlying processes of aging. There also have been startlingly optimistic claims made about the potential benefits of nanotechnology in healthcare. The National Cancer Institute Alliance for Nanotechnology in Cancer held out the goal of eliminating suffering and death due to cancer within a decade of its launch in 2005 (National Cancer Institute Alliance 2005).

The question I am more interested in is whether we *should* put significant resources into “curing aging.” Many years ago in an article in *Deadalus*, Robert Sinsheimer argued that we should not: “Research on aging seems to me to exemplify the wrong research on the wrong problem in the wrong area. We need that talent elsewhere.” (Sinsheimer 1978, 31). In part,

Sinsheimer's argument concerned the consequences of success:

If we propose such research we must take seriously the possibility of its success. The impact of a major extension of the human life span upon our entire social order, upon the life styles, mores, and adaptations associated with 'three score and ten,' upon the carrying capacity of a planet already facing over-population would be devastating. At this time we hardly need such enormous additional problems" (Sinsheimer 1978, 30-1).

It may seem a no-brainer that significantly extending life expectancy would be desirable, but on reflection, there are problems. The most obvious problem of course concerns funding the social security program. But, there are much more serious problems lurking in the role that death plays in nearly all of our cultural and psychological expectations and behaviors.

On the other side of this issue, Aubrey de Grey, a prominent researcher on aging, and an evangelist for funding this research, has claimed that failing to vigorously pursue research to understand and ultimately to control and slow the aging process is tantamount to murder. He writes:

However, we risk being responsible for the deaths of (count them) over 100,000 people every day that this technology [anti-aging technology] is not developed if we delay that progress by failing to speak and act to bring it about. To coin a phrase: I don't know much about ethics, but I know which risk I prefer to take. (de Grey 2004, 265)

The logic behind de Grey's position is simple enough. If controlling the aging process is genuinely within our grasp—and he believes that it is—then failing to do what is necessary to “grasp it” will result in people dying whose lives could have been extended. In effect, the choice not to pursue the research—essentially this means not to fund it—is murdering these people. It seems so simple and obvious.

Nordmann's 'if and then' Syndrome: One difficulty flows from an interaction between our epistemic problem—How well can we predict the likely future success of aging research? — and our ethical problem—Should we fund a major research effort to “cure aging?” In the 2007 issue of *NanoEthics* Alfred Nordmann writes of the “if and then” syndrome. He is concerned about a “radical foreshortening of the conditional:”

The true and perfectly legitimate conditional “if we ever were in the position to conquer the natural ageing process and become immortal, then we would face the question whether withholding immortality is tantamount to murder” becomes foreshortened to “if you call into question that biomedical research can bring about immortality within some relevant period of time, you are complicit with murder”—no matter how remote the possibility that such research might succeed, we are morally obliged to support it. (Nordmann 2007, 32-33).

Life and death, and particularly murder, are ethical trump cards. Whatever one does, it should not include murder. de Grey suggests that calling aging research into question makes one complicit with murder, indeed the mass murder of 100,000 people per day of delay. Nordmann responds in effect, ‘Not so fast. We are not *now* in a position to conquer aging—although we may be at some future date—and so we are not *now* in a position to consider the ethical question of whether withholding immortality is murder. Someday in the future we may be in a

position to take up this ethical question. Today is not that day.'

In addition to taking issue with the radical foreshortening of the conditional in these arguments, Nordmann also argues against the squandering of scarce resources. We have only so much time for serious ethical reflection. Currently existing new technologies raise difficult ethical concerns: How should we conceptualize and protect individual privacy in a world with invisible sensors and wireless networks? How should we conceptualize and protect ourselves from the risks posed by novel nanoparticles? Etc. We do not have time to squander on possible or incredible nano-futures, such as immortality, when we have current pressing problems to solve.

Squandering Science: In a subsequent issue of *NanoEthics*, Rebecca Roache responded to Nordmann's critique. A consequence of Nordmann's position is that ethicists should focus on currently existing or nearly emergent new technologies. Ethicists should steer clear of invented ethical problems arising from speculative scenarios. Focusing on these science fiction scenarios squanders scarce time for ethical reflection. On the other hand, Roach points out that scientists and engineers need not constrain themselves in this way: There is no reason for de Grey not to pursue research on aging—other than perhaps the availability of funds. Indeed, it may be essential for scientists to imagine speculative or incredible futures. Doing so will provide the incentive to put in the necessary long research hours. Furthermore, doing so may be essential to driving conceptual breakthroughs; visionary imagination is part of profound science.

This situation creates an unacceptable asymmetry. Scientists may—and perhaps should—consider “incredible” futures such as ‘curing aging.’ But ethicists have to narrow their concerns to the here and now:

Provided that scientists are allowed free reign to speculate ... whilst ethicists must confine their attention to current or emerging technology ..., it turns out that whereas scientists are bound only by their imaginations in choosing the ends at which they aim, ethicists are restricted to evaluating whichever of the scientists' projects turn out to be promising enough to warrant their consideration.... This raises the risk of scientists squandering their time developing misguided solutions to ethical problems that they are ill equipped to interpret and ... assess. (Roach 2008, 322).

In effect, we have a choice between squandering ethical resources and squandering scientific resources. One could argue that, given such a choice, and given the fact that science costs more, thanks in part to the huge equipment costs, we are likely better off squandering ethical resources.

We see the future dimly: In arguing against the pursuit of research on aging, Robert Sinsheimer pointed out that we have a poor track record in predicting how science and technology will develop. He suspects that we are overly optimistic about the potential dangers posed by new discoveries. Supporting this view, he presents an exchange between Frederick Soddy and Robert Millikan on the possible dangers of nuclear energy. In his 1920 book, *Science and Life*, Soddy wrote:

Let us suppose that it became possible to extract the energy which now oozes out, so to speak, from radioactive material over a period of thousands of millions of years, in as short a time as we pleased. From a pound weight of such substance one could get about as much energy as would be obtained by burning 150 tons of

coal. How splendid. Or a pound weight could be made to do the work of 150 tons of dynamite. Ah, there's the rub... (Soddy 1920, 24).

Millikan responded in a 1930 article in *Scribners Magazine*:

Since Mr. Soddy raised the hobgoblin of dangerous quantities of available subatomic energy [science] has brought to light good evidence that this particular hobgoblin— like most of the hobgoblins that crowd in on the mind of ignorance— was a myth...The new evidence born of further scientific study is to the effect that it is highly improbable that there is any appreciable amount of available sub-atomic energy to tap. (Millikan 1930, 24).

Fifteen years later we had an atomic bomb.

Writing in 1978, Sinsheimer reminded his readers of the Soddy-Millikan exchange to bring home concerns he had about recombinant DNA research. Sinsheimer was worried that recombinant DNA research could pose the same kind of danger as research on nuclear energy. It has now been thirty years since Sinsheimer aired his concerns, and we have had no “recombinant DNA bomb.” We might want to conclude that Sinsheimer was being alarmist. We might want to dismiss Sinsheimer’s argument against research on aging.

But the differences in how nuclear energy played out and how the many biotechnologies made possible by recombinant DNA techniques are playing out are instructive. There is no bomb, but we have come to live with, and we have had to work to diminish a host of worries and risks. Sinsheimer did not anticipate the subtleties of DNA discrimination and health insurance. He did not anticipate “frankenfoods” as a marketing disaster. Recombinant DNA techniques have enabled a vast variety of biotechnological interventions, in agriculture, medicine and other areas. Each area has posed its own set of risks and concerns.

An example from a 2009 news story shows what we are dealing with. Researchers at Oregon Health and Science University have developed a way to replace defective mitochondrial DNA in the egg cells of monkeys. When these eggs become fertilized, they offspring that follow do not have the genetic defects. Moreover, the offspring of these offspring do not have the genetic defects. The monkey’s defective “germ line” has been altered. This genetic intervention does not only change an individual, it alters all the genetic produce of that individual.

Commenting on this development in a National Public Radio news story, bioethicist Arthur Caplan makes clear that this is not simply a good development, a cure for a particular kind of genetic disease:

It goes on forever, because it's passed on from generation to generation. This kind of manipulation is called “germ line” therapy, and it's been considered taboo. For one thing, if there are health risks, they will affect multiple generations. For another, it could open the door to genetically engineering a lineage of people with supposedly superior qualities. This is called eugenics, and many people find that repugnant. It does breach the principle: no germ line engineering. It breaches a promise that many geneticists have made, that whatever else, they're not going down that road. I always thought that promise would be difficult to keep. This particular experiment shows why. (National Public Radio 2009).

Genetically engineering “better” people is hugely controversial, and for good reason. When

recombinant DNA techniques were developed in the 1970s, ethical issues associated with possible germ-line therapies quickly became evident (Watson and Tooze 1981; Silver 1997). But the debate in the 1970s was much broader in scope. Some researchers were concerned about the creation of DNA hybrid monsters that, with the reproductive power inherent in DNA, would be able to reproduce and radically damage fragile ecosystems. The possibility of genetically engineering a race of super humans was only one among many possible downsides to recombinant DNA techniques.

Every new technology has its own history, and the differences between them—be they nuclear energy, recombinant DNA, automotive technologies, anti-aging technologies or whatever—matter. Three kinds of differences are important for my argument about appropriate upstream ethical assessment of emerging technologies. The first concerns having the time to prepare the ground ethically-conceptually for newly emerging technologies. The second concerns the rate at which a new technology embeds itself in the broader social structures it becomes part of. The third concerns scientific and technical precision available at the time of ethical examination. I consider each in turn before concluding with a positive proposal for upstream ethical-societal reflection on emerging technologies.

Forewarned is Forearmed: We have had 35 years to struggle with the issues posed by recombinant DNA techniques. Issues about human enhancement and genetic engineering have been aired and continue to be aired. This new development of the possibility of mitochondrial DNA replacement therapy has arrived in a conceptually rich environment. By contrast, for most people the atomic bomb arrived in an instant. This is a significant difference, for almost immediately we were behind in trying to think through the implications of nuclear energy. Moral, political and regulatory concepts had to be created very quickly, and not always with the best results.

This new research on mitochondrial DNA replacement techniques is appearing on the scene after researchers and bioethicists have had time to air and debate these issues. This means that we are in a much stronger position to direct, control and/or regulate such technologies. This was not the case with nuclear energy, where regulation had to play catch up. Caplan worries that it will be difficult to prevent germ-line interventions because of their power to do good. Eliminating a disease caused by a genetic defect is a powerful incentive to press on. Absent long-standing and carefully argued reasons against germ-line intervention, it is very difficult to see how such work could be effectively controlled or regulated. It still may not end up being effectively controlled or regulated. But those who favor regulation and/or control have reasons to hand to support their case.

This difference between recombinant DNA techniques and the development of nuclear energy suggests that we should support upstream ethical reflection on speculative emerging technologies. Difficulties arise when technological change runs ahead of the conceptual-ethical frameworks for its social control. Nordmann is wrong. There is substantial value to getting the arguments out ahead of time. Forewarned is forearmed.

Rate of Change: Not so fast. Another difference in how technologies develop points to a different conclusion. Nordmann is right. We should focus on the here and now, and not waste our time with speculative fantasies.

The rate of change in the emergence and social embedding of a new technology is an essential dimension to constructive consideration of an emerging socio-technical hybrid. Our values change. In part, our values change in response to emerging technologies. See

Figure 1.



Figure 1

It is hard to believe that anyone living in the kind of pastoral landscape shown in John Penniman's painting, "Meetinghouse Hill, Roxbury Massachusetts," would have found the freeway scene very attractive. Yet these freeways do have a kind of attraction, and they certainly facilitate transportation that would have been inconceivable in 1799 painting. We have come to live with cars and all the good and bad that they bring with them.

I do not suggest that we value human life less because of the car. Rather, I suggest that we place a very high value on the kind of transportation afforded us by the car. In part we place such a high value on this because of the culture that has co-evolved with the car. The importance of the car—the value we place on it—has developed with the car and the systems that it depends on. We simply could not excise the car from contemporary life without causing massive disruption. So we accept, while working to mitigate, the dangers of cars.

There is a critically important feedback loop between our values and the socio-technical systems with which we interact. Since risk is, in part, a function of our values, the risks posed by a new technology themselves evolve along with the on-going socio-technical development of a new technology. Since, we cannot well-predict either how a new technology will develop, or be socially embedded, and more crucially, since we cannot then predict how our values will develop, it makes little sense to assess speculative technologies in the distant future. We simply have little idea what will be important to us when the time comes. Nordmann is right. We should wait to do this work, until we can reasonably know what the risks and issues really are.

There is one other critically important aspect to rate of change. Change in itself is disruptive, particularly changes that reach to core values. Mortality and lifespan are integral to much that we value. Lifespan changed significantly during the 20th Century. In 1900 the global average lifespan was 31 years; by 2005 it had become 65.6 years (World Health Organization 2006). What is the problem, then, with pressing ahead with research to push these numbers even farther? This argument has several flaws. In the first place, we have not increased expected lifespan for persons who survive childhood by so much. Rather we have made significant strides to diminish mortality during childhood, which brings the overall average way down. But, for my purpose here, the significant point is that this change occurred over the period of 100 years, long enough for social systems and expectations to adjust. I could imagine social systems adjusting without too much of a hiccup to average an increase in the lifespan to 140 or 150 during the next 100 years. But this is a far cry from the change anticipated by Kurzweil and others. Such a change would not allow Kurzweil to live long enough to live forever. *That* rate of change would be very disruptive.

Precision: There is one more important difficulty to upstream ethical assessment: We don't have much precision either about the scientific and technological possibilities on offer, or about the social and ethical issues that these possibilities might raise. Precision typically improves as we learn more. But for many emerging technologies the subtleties matter. We are concerned about the loss of privacy that a combination of information technologies and new implantable medical diagnostic technologies may allow. I might have an implanted device to test my blood for proteins associated with cancer or heart disease. The device might be set up to communicate its "findings" wirelessly. But this information could be intercepted and my medical privacy breached. The devil here will be in the details. What, how and when does this imagined diagnostic device communicate? Answers to these questions will either put this privacy question to rest or not.

Does the possibility of germ-line mitochondrial DNA replacement therapy raise the specter of eugenics? I do not know the answer to this question. It depends on what we can change by

making alterations in mitochondrial DNA. Are the kinds of alterations that we can make eugenic, at least eugenic in a sense that we should be alarmed about? This depends on how we define disease eradication as opposed to human enhancement. Surely eradicating a disease is a kind of enhancement, but perhaps it is not one we want to avoid. Or not. The scientific and conceptual details matter, and these details take time to emerge.

Reliable versus Speculative Claims: Consider the following four questions:

- (1) Was there specific scientific evidence in 1930 for potential health risks from exposure to radiation?
- (2) Is there today specific scientific evidence for potential health risks from exposure to some nano-materials?
- (3) Was there specific scientific evidence in 1930 for the rapid extraction of energy from radioactive materials?
- (4) Is there today specific scientific evidence for indefinite life extension by any known means?

I suggest that the answer to the first two questions is “Yes,” but “No” to the last two. This marks an important distinction for how to profitably and constructively consider the ethical issues raised by the technologies involved.

When there is specific scientific evidence available to answer a given claim, we can call it a “reliable claim.” In 1930, it was reliable to claim that exposure to radiation posed a health risk. Today it is reliable to claim that exposure to certain nano-materials poses a health risk. On the other hand, in 1930 it was a matter of speculation whether we would be able to rapidly extract energy from radioactive materials. This is a “speculative claim.” Clearly the consequences of our being able to rapidly extract energy were—and are—extensive and significant. But we had no reliable reason to believe that this was in the cards in the reasonably near term. I would say the same today about the possibility of indefinite life extension. It is not a piece of wild speculation—extravagant science fiction—to suppose that this might be in our future, and it was not wild speculation in 1930 to propose that radioactive materials would be a powerfully important source of energy. But we have no specific scientific evidence that supports this possibility in the reasonably near term.

We need to deal with the ethics of reliable and speculative claims differently. With reliable claims we need to sharpen our understanding of the technology and its likely embedding in various communities. We need to seek specific ways to mitigate the potential harms. Given that our scientific and technological understanding of what lies behind reliable claims is well-developed—this is why they are reliable claims—we are in a position to answer questions about likely harms, and to develop ways to avoid them. We should be aiming to *close* outstanding questions, scientific, technological and societal. Those charged with “solving ethical issues” arising from emerging technologies about which we have a reliable understanding, should aim to deliver a justifiable normative *product*: What are the specific risks to radiation exposure? How should we weigh whatever benefits we might gain from some radiation exposure against these risks? How toxic are carbon nanotubes, and what exposure in the workplace is acceptable, what not?

Normative Process versus Normative Product: With speculative claims it makes no sense to try to produce specific answers to questions in this manner. With scientific questions, we simply need more evidence. With ethical questions it is premature to provide answers

because we don't know what the specifics of the issues are going to be. A cost-benefit analysis would suffer from the standard problem, garbage in-garbage out. Lacking either scientific or ethical precision, we should not aim to provide definitive answers to questions. To do so would be premature.

On the other hand, I think there remains ethical work to do with speculative claims. It would be beneficial—in my view—if there were people thinking the consequences of significant lifespan extension. One can do easy computations about social security, and or retirement packages. But the much more interesting—and important—issues will take more time and thought. What happens to marriages when one might live long enough for a 100th anniversary? How do we feel about accidental death? Is it more of a loss for a teenager to die in a car wreck when he or she might have lived to 150 or does lifespan not make a difference? What is the role of death in institutional change? All of these questions are difficult. None have clear answers. It would be a mistake to try and answer such questions. But it is worthwhile to raise the questions. It is worthwhile to put the work in to think up the questions, whether or not we can answer them. Having the questions in hand will prepare the ground for whenever—and if—an actual specific kind of lifespan extension presents itself.

It is a normative *process* that speculative claims need, not a normative *product*. Questions such as those that I mention here don't have answers, because attempts to answer them lead to more questions. That is a good thing with speculative claims. We need to examine—or “deconstruct” to use more contemporary language—the assumptions concerning lifespan extension. Is aging a disease in need of a cure? Can we distinguish seeking a cure for a specific cancer from seeking a cure for aging by thwarting the various causes of death? What are the roles that mortality plays in understanding human existence, and how will this understanding change if we change the mortality equation? Does the rate of change in expected longevity matter? All of these questions lead to more questions, and the process of digging into such conceptual difficulty—but important—terrain is informing. It will help us to prepare for the future, however it presents itself.

Beyond examination itself, the normative process I have in mind needs to involve multiple players. This is not a game only for philosophers—although I certainly think it is an important and appropriate game for philosophers. I would want those involved in research on aging to be part of this, both because they bring to the table a realistic understanding of what is possible, and of what is sought through the research. But many other disciplines have much to offer. Lifespan is critical to culture, and there is much that anthropology should bring to these kinds of discussions. I could carry on with perhaps every discipline on the campus, and many stakeholders beyond the academy. The point is that the process I imagine is a broadly-based on-going serious dialog about these issues. It should not aim at providing answers. It should aim at providing questions. It should be aimed at helping our ethical-conceptual understanding evolve with and help direct the on-going process of realizing a new technological possibility.

Normative Processes and On-going Socio-Technological Change: In short, I propose that we distinguish between reliable and speculative claims. With reliable claims we should aim at a normative product. With speculative claims we should aim at a normative process.

Societal and ethical issues that arise from reliable claims come with sufficient scientific and ethical-conceptual precision to allow us to seek definitive normative answers, a normative product. Societal and ethical issues that arise from speculative claims do not come with sufficient precision to allow meaningful definitive normative answers.

We need to engage the issues raised by speculative claims with broad-based normative processes. These processes should raise societal and ethical questions, not answer them. Processes of this sort will facilitate a less disruptive, smoother, co-evolution of our values with our socio-technical systems. Processes of this sort will conceptually forearm us so we can better understand, control and/or direct the development of an emerging socio-technical system.

Normative products, specific ethical and/or legal judgments, are appropriate when we know enough to settle issues in a way that is consistent with the scientific, technological, societal and ethical facts presented to us. Normative processes are appropriate when dealing with emerging and rapidly evolving socio-technical systems.

References

- de Grey, Aubrey D. N. J. (2004). "An Engineer's Approach to Developing Real Anti-Aging Medicine," In Stephen G. Post and Robert H. Binstock, eds. *The Fountain of Youth: Cultural, Scientific, and Ethical Perspectives on a Biomedical Goal*, Oxford: Oxford University Press, 249-267.
- Kurzweil, Ray and Grossman, Terry. (2004). *Fantastic Voyage: Live Long Enough to Live Forever*. London: Penguin Books.
- Millikan, Robert. (1930). "Alleged Sins of Science." *Scribners Magazine* 87(2): 119-130. All quotations are taken from Sinsheimer 1978; page references are to that publication.
- National Cancer Institute Alliance for Nanotechnology in Cancer. (2005). "NCI Alliance for Nanotechnology in Cancer, Centers of Cancer Nanotechnology Excellence, Summary Transcript, October 3, 2005."
http://nano.cancer.gov/alliance_awards/resources/CCNE%20telecon%20summary%20Oct%203%202005.pdf, accessed on August 23, 2009
- National Highway Traffic Safety Administration. (2009). "*Motor Vehicle Traffic Fatalities & Fatality Rate: 1899-2003*."
<http://docs.google.com/gview?a=v&q=cache:oFrB1pyrCvoJ:www.saferoads.org/federal/2004/TrafficFatalities1899-2003.pdf+annual+traffic+fatalities&hl=en&gl=us>, accessed August 27, 2009.
- National Public Radio. (2009). "A Potential but Controversial Fix for Genetic Disease."
<http://www.npr.org/templates/story/story.php?storyId=112248236&ft=1&f=1001>, accessed August 27, 2009.
- Nordmann, Alfred. (2007). "If and Then: A Critique of Speculative Nanoethics." *NanoEthics*, 1: 31-46.
- Roache, Rebecca. (2008). "Ethics, Speculation, and Values." *NanoEthics*, 2: 317-331.
- Silver, Lee. (1997). *Remaking Eden: How Genetic Engineering and Cloning will Transform the American Family*. New York: Avon Books Inc.
- Sinsheimer, Robert L. (1978). "The Presumptions of Science." *Daedalus*. Spring 1978, 23-35.
- Soddy, Frederick. (1920). *Science and Life*. London: John Murray. All quotations are taken from Sinsheimer 1978; page references are to that publication.
- Watson, James and Tooze, John, eds. (1981). *The DNA Story: A Documentary History of Gene Cloning*. San Francisco: W. H. Freeman and Company.
- World Health Organization. (2006). "Health, History and Hard Choices: Funding Dilemmas in a Fast-Changing World." http://www.who.int/global_health_histories/seminars/presentation07.pdf, accessed August 31, 2009.

Co-Production of Public Uncertainty: Strategic Uncertainty In Nano Debates

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This entire piece could retell the saga of climate change and the incapability of the West and the USA to come to terms with the overwhelming evidence that humans are affecting climate change. The G W. Bush administration chose two different tactics: attacking the critics (discrediting the scientific bases of climate change) and forwarding uncertainty as the grounds for inactivity in reducing greenhouse gas emissions. While this story is very entertaining, it has been told many times and will not be retold here. Whether the story will be heeded in time to do anything to reduce the human impact on climate change is yet to be seen. The primary lesson to be learned has more to do with the strategic function of uncertainty. The following examines some of the work associated with the Public Communication of Science and Technology Project at North Carolina State University (PCOST.org), which is under my direction.

Enter nanotechnology. The National Nanotechnology Initiative (NNI) is not an agency and it has no dedicated budget. The National Nanotechnology Coordination Office (NNCO) housed in the National Science Foundation (NSF) is just that, an office with a relatively meager budget. Twenty-five government departments and agencies are members of the NNI and each allocates a portion of its budgets to research and development under the rubric of nanotechnology yet they retain control over their budgets. While the US has a standardized definition for nanotechnology, internationally there is some disagreement. We are slowly developing consensus in the nomenclature about nanoscience, nanotechnology, and nano health and safety. We have much more disagreement over characterization and measurement, hence the growing interest in standards.

It is my premise: public uncertainty reflects expert uncertainty and uncertainty has powerful strategic importance for agenda setting. Purveyors of uncertainty include: government, industry, scientists and engineers, media, and non-governmental organizations.

Uncertainty is a function of one or more of the following:

- Inadequate scientific knowledge,
- Insufficient evidence,
- Inability to generate professional consensus, and/or
- Invented phenomena built by a community or communities.

Why so much uncertainty? American research and development has led to some mind-boggling breakthroughs. However, more findings do not necessarily decrease uncertainty. Indeed, contemporary science seems to increase uncertainty despite its best efforts. There are at least four primary reasons science is being challenged: (1) the event horizon for breakthroughs is creeping closer and closer; (2) the grey area between what we perceived to be real rather than fictional has widened; (3) there is less certainty

associated with scientific and technical claims of all sorts due to the proliferation of subjects to study and ways to study them; and (4) there are many inexpert publics (hence the use of the term “inexpert” below to refer the folks populating what has been called the public sphere and public science) and there is no “one size fits all” solution when it comes to the mitigation of risk perception by many inexpert stakeholders. As such, decision-making is more challenging, risk estimates are less accurate, and uncertainty abounds. Consider the following four phenomena in greater detail.

Event horizon creep

Change exceeds our capacity to foretell what is on the horizon and our capacity to forestall developments that might threaten our values and mores. Kurzweil (2005) discussed a similarly conceptual problem he calls “Singularity”. In addition, leapfrogging technologies have accelerated development projections. For example, smart phones are introduced without the transitional steps of personal computers. Most prognostications have been exercises in wish fulfillment. Most stakeholders have every incentive to exaggerate promises and underestimate drawbacks and reservations especially if it involves things like grant funding.

Boundaries between fiction & nonfiction

Narratives built on unreal or fictive claims have more space to acquire rhetorical validity. Since experts and inexperts tend to perceive risk differently, it is insufficient when experts use assurances and rebuttals to affect inexpert sentiments. Even if assurances are offered, they are couched in high levels of uncertainty. In addition, more and more experts have entered these frays and offer perspectives that are often inconsistent and sometimes contradictory. In situations when the string of arguments has low certainty values, the inexperts turn to fictive or exaggerated claims awarding them more reliability than they objectively deserve.

Explosion of uncertainty

This is a function of the increasing access to information fostered by advancements in scientific procedures and capabilities and in information access, especially sophisticated search engines on the World Wide Web. In addition, colleges and universities have nearly unlimited access to libraries and databases of all sorts. As more research is funded, more data is produced. Attempting to separate useful information is time consuming. As results become much more specialized, the body of experts with the capacity to vet procedures and conclusions shrinks. For example, the tendency to view policy as inherently uncertain has perverted the debate over approaches to assure health and safety toward a hard reading of the precautionary principle.

Proliferation of audiences & stakeholders

The fourth phenomenon recognizes that the public spheres of the 18th and 19th centuries, which Dewey and Habermas described, are not recognizable today. Today’s publics and counterpublics include women, people of color, the subaltern, and the poor. The continuing trend in the late 20th and early 21st centuries towards identity politics and intersectional public sphere theory have added new groups of players, such as the ably challenged, gays and lesbians, and other traditionally marginalized voices. Stakeholders are more difficult to identify because they are inter-sectional: wealthy

women of color and gay white males cross clear identity classifications making demographic assumptions about risk aversion and technology adoption extremely problematic. Finally, it has grown incredibly challenging to find particular sensibilities that can be situated within any single group because no single member of the public can be found in one single public or counter-public.

The following examines the third and to some degree the fourth phenomenon itemized above.

Research context: Human and environmental toxicology

No research in risk studies approaches the subjects of risk and uncertainty free from context. Whether discussing investment or environmental protection, every researcher examines a series of variables against a subject field. Recently at PCOST, we have centered a major portion of our effort toward human and environmental toxicology of nanoparticles and other emerging technologies for four reasons.

First, the field of nanoparticles toxicology or nanotoxicology was selected to parallel the NNI, NSF, and National Institutes of Health (NIH) associated funding in environmental health and safety (EHS) related toxicology research. In addition, we have our current Nanotechnology Interdisciplinary Research Team (NIRT) working in intuitive nanotoxicology, we participate in the National Center on the Environmental Implications of Nanotechnology located at Duke University, we maintain two blogs in nanoscience, and PCOST has undertaken growing dialogues in a broad range of emergent technology from food science to synthetic biology. We anticipate risk and uncertainty research to play a role in each of these activities.

Second, this project will use human and environmental toxicology of nanoparticles and synthetic biology as a subject field because the participants and the campus are expert in this field. Their connections in the world of “nano” toxicology research, environmental studies, and business are significant and a major grant to examine human perceptions of toxicological information is proceeding nicely.

Third, perceptions of risk and associated values involving human and especially environmental pollution have not received much attention in the inexpert arena for nearly a decade. In addition, these perceptions are difficult to assess given the chronic nature of the hazards associated with risk analyses and the difficulties associated with establishing dosage and exposure variables to nanoparticles: the hazards occur at a time in the future, a period populated with new tools, response strategies, and values.

Fourth, inexpert audiences’ uncertainties about environmental contaminants, for example, are often based on a sense of “not knowing” about these contaminants because they are invisible, because health problems related to them may not show up for years, and/or because information about them isn’t available or is not provided by authorities (Adeola 2000, Brown & Mikkelsen 1999, Hallman & Wandersman 1992 and Irwin & Wynne 1996).

Inexperts, environmental policy and decision-making

Many inexperts can barely define “environmental values” and most have no actual scientific or public policy experience with an environmental issue. We expect environmental issues associated with life cycle processes of applied nanoscience will not fare any better. Finally, we believe uncertainty is constituted by more than merely insufficient information and we have noted repeated examples of the use of uncertainty as a strategic tool in agenda setting (Berube 2008).

Current toxicology research amplifies calls for more information, which we contend, will never be met. Both inexpert and expert audiences have soundly rebutted the deficit theory of scientific knowledge as the primary reason for uncertainty. For example, the inexpert audience has already self-selected themselves to remain outside an expert world that is pseudo-religiously affined to scientific information. Finally, of course, information can be used to manipulate uncertainty in one or more desired directions (Brashers, Neidig, Haas et al 2000).

Furthermore, it is important to note that the research and findings associated with how risk and uncertainty intersect in the subject field of toxicology of nanoparticles will have significant implications as emergence become part and parcel of all things novel in science and technology. In addition, nanotechnology is not only a textbook example of an emergent technology and boldly inter-disciplinary, but also conceptually fuzzy (Chen & Hwang 1992) and unsettling for many inexperts.

Working from the above suppositions, our work is building and testing descriptive decision-making models that demonstrate clear differences between how experts and inexperts account for both risk and uncertainty. These models provide opportunities for diagnosing and treating risk and uncertainty across a range of inexpert stakeholding audiences. In addition, this work enables us to develop and implement middle school, high school and university instructional modules on decision-making, risk, and uncertainty.

Our project necessarily began with a comprehensive review of the “Risk and Uncertainty Studies” literature. A project funded by the NSF that we completed for the NNCO during the summer of 2008. As such, the following section articulates some of this work-to-date and how it informs the problem of emerging technologies. We begin by emphasizing the fundamental role of uncertainty as a meta-heuristic of sorts in what has been termed “new technologies” and the problem this necessarily presents for human health and environmental decision-making. Then, we build this claim into our key concepts: Uncertainty, Risk, Decision-making, and Public Science, which we see as an inevitable element of scientific uncertainty. The discussion that follows views uncertainty as a problematic building block that necessarily informs risk – especially in inexpert decision-making. Thus we position these concepts as mutually constructing but built from the initial ways in which people address and resolve uncertainty. For this reason, the discussion pays considerable attention to the ways uncertainty has been considered and addressed in the literature. We then conclude this section by linking these concepts to articulate some of the key contemporary issues we will address in this project, an example of which is a re-conception of the *precautionary principle* as a guiding strategy for risk avoidance.

Uncertainty & new technologies

The paradox of science is that our world has become more predictable and controllable and more complex and chaotic at the same time. As such, the core of this work involves a better understanding of “risks” and “uncertainties” given a new cartography of risk studies. Over the last decade, the rise of various new technologies that assume and actually create uncertainty (nanotechnology, genetic modification, and synthetic biology) requires researchers in the field of risk studies to better examine new complexities and assumptions of risk and certainty in a way that will allow us to sufficiently plan for the decades ahead.

Working within the intersection of nanoscience and human and environmental toxicology, this project offers a better understanding of the concepts of uncertainty and risk. Our goal is to provide new ways to examine both these classes of variables to assist multiple stakeholders in efforts to test and vet the environmental, health and safety (EHS) footprints of nanoparticles. In addition, what we learn about this case will prove invaluable in understanding how certainty and risk interact and how this interaction will open up new possibilities and opportunities in understanding hazards and responding to them.

This project has been examining uncertainty as a complex phenomenon incorporating inadequate understanding, incomplete information, undifferentiated alternatives, and imprecise methodologies of foresight. But the project also considers deployment – uncertainty as a strategic move (especially in advocacy). Each of these variables does not function equally in cases of uncertainty. One may dominate the risk landscape more than the others at any given time. Sometimes some are relevant while others are not, but there is seldom an instance when only one variable defines the state of uncertainty. Learning more about this complex interplay is foundational to our work.

On uncertainty and science

Given the pace and change and the complexity of emerging technology, uncertainty will predictably be the mantra of the inexpert and expert audiences for some time to come. Uncertainty is a function of many unknowns but as a socially constructed reality it is affected by many non-rational variables introduced by inexpert audiences. For example, while risk is clearly a function of some hazard, moderated by dosage and exposure variables, these variables themselves are also affected by the uncertainties associated with hazard, dosage, and exposure – and many of these uncertainties come from science, the experts.

As science attempts to increase certainty, oftentimes scientists add contingencies to their claims to reduce the breadth of their claims within a subject field. However, as a claim “moves into more formal and more universal settings, it often loses some of its contingencies” (Zehr 1999, p. 5), in turn counterproductively reintroducing uncertainty. This is especially true in reportage of scientific findings for inexpert audiences, as scientific information is shared with stakeholders who have neither a technical background nor a cadre of translators stepping forward to assist them. The role of the media and non-governmental organization is beyond this chapter length articles and will be addressed in the near future elsewhere.

Uncertainty serves constitutive functions for researchers as well. “Because science involves producing knowledge about what was previously unknown, uncertainty is a norm and necessary characteristic of scientific work.... [S]cientific uncertainty is not simply something that scientists try to eliminate through their research. Scientists also actively construct and effectively use it in scientific articles and in public science contexts” (Zehr 199, p. 3) both as a hedging rhetorical strategy and as leverage to increasingly fund their research agenda. As a result, some have gone as far to argue: “Scientific work does not just reduce uncertainty; it actively constructs it.... Science is as much an uncertainty generator as it is a certainty producer” (Zehr 1999, p. 4).

On the literature

Traditional communication approaches toward uncertainty lie along three theoretical lines of thinking: uncertainty reduction theory (Berger & Calabrese 1975), problematic integration theory (Babrow 2002 & Babrow 1995) and uncertainty management theory (Brashers, Neidig, Hobbs, et al 2000). All three postulate uncertainty as an autonomous cognitive state affected by language. In addition, several common themes emerge in this literature about what uncertainty might entail, including (1) the perception of “not knowing,” (2) emotions, and (3) communication processes. In addition, uncertainty management theory accommodates the willful obfuscation and the seeking of vague, imprecise information. Put simply, sometimes it is deemed profitable to claim uncertainty to mask a decision already made and to avoid dealing with a negative reaction. False claims of certainty exhibit confidence but may have the effect of persuading oneself of being certain.

While uncertainty may exist prelinguistically, its significance merges in the process of verbal interaction (real or imagined) (Braddock 2001). Powell et al (2007) pointed to several factors shaping uncertainty perceptions that have not yet been clearly addressed, including “knowing” or perceived knowledge, the role of trust, risk judgments and issue relevance, information exposures and interpersonal discussion, and socio-demographic and contextual factors. We find some of the current approaches toward uncertainty both simplistic and limited and see a need to re-examine these premises and approaches.

The fundamental assumption *more information reduces uncertainty* ignores the obvious: individuals select between sources of information for many reasons, only one of which is its intrinsic explanatory quality. Other variables are at work to explain why a minister or a member of one’s family may trump the opinion from a scientist – even when the information is outside the expertise of the non-scientific sources. Information can be avoided (leaving an envelope unopened) and adaptation to a state of uncertainty can even become a defense mechanism (see research on AIDS patients) (Mishel 1990). Put simply, more data is not sufficient to reduce uncertainty.

Technical communication theorists have contended uncertainty is multilayered and syntactically diverse and as such these phenomena need to be unraveled (Brashers & Babrow 1996). People are embedded in layers of context that subject them to complimentary as well as contradictory forces. Theories of uncertainty management need to examine the ways in which uncertainties are interconnected (Babrow 1995). For example, complications in the health of an environment from ambiguous symptoms, degrees of hazard, and unclear solutions can cause uncertainties in financial wellbeing, personal relationships, and so forth. In addition, the spatio-temporal dimensions of

uncertainties are under-investigated (Babrow & Klein 2000). Uncertainties can be brief or ongoing. The level of uncertainty can increase or decrease over time, as people grow accustomed to its presence.

Often, uncertainty about one phenomenon will bleed into another (contagion) though the basis for uncertainty about one element of a class of phenomena may not be universally shared by other elements in that class. On the other hand, in cases where there is little if any transference or contagion we find uncertainty anomalies, the grounds and warrants for which are important variables in understanding inexpert perceptions. These anomalies may be instrumental in reducing uncertainty as well. Heuristics associated with expert perception while relevant are not explained here.

We clearly applaud the treatment of uncertainty as a subjective state not easily eliminated by more information. We also agree with the external + internal view of uncertainty whereby individuals attribute uncertainty to some phenomenon in the outside world while locating the source of uncertainty within the individual (Kahneman & Tversky 1982). As Heyman et al wrote, "people make probability judgments based on what they know as much as or more so than on what they don't know" (Heyman, Henriksen & Maughan 1998). This position helps explain some discrepancies in opinion studies about nanotechnology to date. In addition, Powell et al's tag of trust as a variable in uncertainty is worth further testing. As Johnson has noted, "It is still unclear whether uncertainty in risk estimates is an independent issue in risk communication, or whether attitudes toward it merely reflect other attitudes, such as whether one can control risks to oneself or trusts the source of uncertain risk estimates" (Johnson 2003).

Slovic and others have demonstrated risk judgments are related to perceived uncertainties about risks. The more important the risk, presumably, the more willing an individual may be to reduce their uncertainty about the risk. However, this phenomenon is much more complex than it seems given high risk populations who tend, at times, to make little, if any, effort to reduce their uncertainty regardless of the risks involved, a phenomenon that surfaces regularly in health communication, oddly enough including deadly diseases from HIV to H1N1 exposure.

Finally, while socio-cultural experiences, including formal education, disposable income, and so forth might be related to understanding scientific information, there still remain too many instances where privilege remains correlated to uncertainty, such as inexpert perceptions of global warming and climate change. While we applaud much of this research and hope to see more of its kind, we feel the cartography of risk and uncertainty studies remains relatively flat at this time.

The construction of uncertainty has many actors working on many different levels using a wide array of tools or strategies. However, research to date does not fully appreciate the clash between organizational cultures and how the tension and intersectional sensibilities of experts complicate the construction of effective risk messages when addressing issues with moderate to high levels of uncertainty.

Finally, thinking about risk and uncertainty seems overwhelmingly limited by an uncertainty reduction paradigm. Deciding which variables should receive more attention than another or others and whether one or more should be discounted altogether remain highly disputed. At times, we may need to simply accept the thesis that uncertainty

cannot always be reduced and that our efforts to reduce uncertainty at nearly all costs may be pathological (Merry 1985).

The conceptual construction of uncertainty rings differently to different stakeholders. How a regulator approaches uncertainty seems at odds at how the in-experts approach uncertainty. We must also consider that uncertainty can be a tool used by some stakeholders to forward their own agendas, often self-serving but sometimes altruistic but misinformed.

Uncertainty can be introduced as a tactic to garner additional resources. For example, toxicologists seldom, if ever, admit there exists sufficient data to make a reasonably certain decision.

As we have often seen in the nanotechnology literature, some groups have vested self-interests in maintaining high levels of perceived risk and others benefit from claims of high levels of uncertainty (Berube 2008a). Some stakeholders emphasize uncertainty as much as risk to amplify a hazard, raise the visibility of their organization or issue, and shake loose heightened levels of constituent funding. Finally, scientists use uncertainty to protect themselves against charges of dogma and bias and as a technique to provide a boundary between themselves and policy makers they advise (Zehr 1999).

Uncertainty is a rich and dense construct and needs another examination by scholars who will approach uncertainty, as something not necessarily resolved by more data.

On risk and its social construction by in-expert audiences

Risk is built on uncertainty. Indeed, the dependent variables affecting uncertainty may be the proverbial fly in the ointment when designing risk communication messages between expert and in-expert audiences. For in-expert audiences, risk is much more than an equation; risk is a social construction and must be examined as such. This consideration of risk has not been well developed in expert communities that largely impose their own highly nuanced concept of risk when engaging with various in-expert audiences. In other words, in-experts understand risk in a substantially different way from experts under most circumstances, hence perceptual discrepancies between them.

It has been repeatedly demonstrated that uncertainty and risk ambiguity remain important concepts in public communication about phenomena such as science and technology (Kahneman, Slovic & Tversky 1976) and uncertainty is a major obstacle to decision making (Gigenrenzer 2002, Orasanu & Connelly 1993, McCasky 1986, Brunsson 1985, Corbin 1980 & Thompson 1967).

In public contexts, risk is an equally difficult and contradictory phenomenon. Here, the word “risk” may have as many different definitions as the word “paradigm”. While experts examine hazards against additional variables such as dosage and exposure, the public uses mental shortcuts or heuristics that discount dosage and exposure values. As the same time, publics emphasize experience, history, and folklore, variables that are regularly discounted in expert communities.

Consequently, in the context of new technologies that inevitably engage and interact with in-expert communities, we need to better understand whether amounts of certainty are related to how in-experts make accurate and useful decisions (whatever those

decisions may be). How can we better enable non-experts to make sufficiently precise estimations about risk so that their eventual decisions might be prudent and thoughtful is one of the primary goals of our work.

On risks and decision-making

Lipschitz and Strauss asked an important question a decade ago. “Are there systematic relationships between different conceptualizations of uncertainty and different methods of coping?” (149). Uncertainty cannot be conceptualized as an umbrella term under which all unknowns are stored. If all uncertainties are not equal then knowing what we may be up against may enable us to fashion a more appropriate response. Uncertainty has to be more than not knowing.

Most people make efforts to manage their uncertainty rather than eliminate it with more and more data. Since uncertainty reflects individual-level emotions and cognitions as well as social and contextual factors including (1) the content of perceived knowledge about risks; (2) social perceptions (e.g., trust in government, perceived risk to others); (3) perceived issue importance; (4) interactions with mediated information and interpersonal discussions; and (5) socioeconomic and contextual factors (Powell et al 2007), eliminating uncertainty, read as missing data, may be a loser’s game.

Approaches to examining uncertainty and risk from a decision-making perspective typically and popularly include Subjective Expected Utility (Wakker 1993) calculation to games involving Monte Carlo simulations (Davis & Keller 1997). However, the bulk of this literature seems to relate decision-making strategies to a version of framing (whether a situation is presented as an opportunity or a threat) (Jackson & Dutton 1988) and to outcome history. In outcome history, a person-situation interaction characteristic is defined as the degree to which the decision maker believes that previous risk related decisions have resulted in successful or unsuccessful outcomes (Sitkin & Weingart 1995). These approaches are coping rather than certainty directed decision-making.

We know decision makers tend to use one or more of five strategies to cope with uncertainties: reducing uncertainty, assumption-based reasoning, weighing pros and cons of competing alternatives, suppressing uncertainty, and forestalling (Lipschitz & Strauss 1997). We know much less about how decision-making organizations cope, especially in cases when the process remains unstructured (Mitzburg, Raisinghani & Théorêt 1976). There is some evidence when people cannot find a way to reduce the uncertainty in their lives, they make decisions regardless of uncertainty by employing non-rational and irrational criteria (shortcuts or heuristics), change the ways they make decisions, or build a cocoon of uncertainty to protect themselves from the complexity of the world out there (Merry 1985). Similarly, we’ve learned when experts confront uncertainty, they tend to increase or improve the data flow; reclassify data that once was accepted to discount it or was once rejected in order to accommodate it; or reject a whole way of thinking, opting for a new paradigm.

On “Public Science”: A necessary outcome of uncertainty?

The context in which scientists make scientific claims before non-scientists has been touted *public science* and seems to jointly emerge from scientists who are interviewed and from writers themselves (Zehr 1999). As such, public science has animated, if not amplified, in the Kasperson (Kasperson et al 1988) sense, the association of risk and

uncertainty with science and technology. For example, quite regularly, in an attempt to appear balanced, reporters provide podiums for individuals advancing untenable claims. Or, alternatively, certain basic assumptions may be simply overlooked. As Zehr has argued, “in the more limited space of public science, sometimes tacit knowledge may be left out, leading to an appearance of contradictory claims” (Zehr 1999, p. 10). Indeed, given the numerous and contradictory purposes of public science, “uncertainty is a much more common feature of public science than it might appear to be on the surface, and it could be intrinsic to public science itself” (Zehr 1999, p. 16).

More risk studies are examining the media (Coleman 1993, Friedman, Dunwoody & Rogers 1999, Hansen 1993 & Hornig Priest 2001) and many projects involving public engagements are testing the role communication can play in risk estimation. At the same time, other research has shown that inexperts, by and large, do not aggressively seek scientific information (Bush, Moffatt & Dunn 2001). All of this shows that inexpert audiences pose special challenges. They attend to more heterogeneous sources, for example, and they seek more ephemeral and gray sources for amplification and attenuation, such as the web or popular media. Public science typically features multiple speakers with multiple versions of knowledge and this cacophony of sorts can result in a range of challenges. In other instances, scientists may find the appearance of uncertainty managed by other parties, such as the media or civic advocacy groups, to ends contrary to those of the scientists.

Behavior of this sort tends to produce uncertainty spirals, uncertainty out of control. Inexpert stakeholders find themselves not only confused but also excluded from decisions that they believe will influence their lives, families, and communities.

The following draws from one of the most maligned principles in debates over uncertainty and emerging technology.

A Research Problem: Re-Examining the Precautionary Principle

Given the power associated with uncertainty and risk to stymie reasonable responses to science and technology phenomena, there has been a resurrection of precaution as a viable response to emergent technologies. While some applications of a technology might be sufficiently provocative to consider justifying foregoing development, there are a plethora of pragmatic response systems: avoid one approach but consider another, engineer around the provocative characteristics associated with the technology, provide sufficient information for informed decision making to occur, demand screening or regulatory protocols to protect health and safety, and so forth.

The heuristic of contagion is predicted on the assumption that any exposure is disrupting and polluting. For example, we tend to view food that has touched the ground as contaminated by the ground, and therefore unfit to eat, or we view a person who has touched a diseased person as likely to carry the disease (regardless of the actual contagiousness of the disease). Thinking of this sort justifies responses like moratoria (Gilovich, Griffin & Kahneman 2002).

In this section, we use the concepts introduced above (uncertainty, risk, decision-making, and public science) to advance a research agenda. In short, we propose a re-conceptualization of the *precautionary principle* as it applies to new and emerging technologies. This section of the text is primarily illustrative and used to animate some of

the ideas mentioned above. DO NOT conclude this is the beginning and end of this project. We propose much more. We recognize this as a problematic assertion. To be clear, we do not advocate dispensing with the precautionary principle. Instead, we argue that the principle needs to be better articulated to enable new technologies to emerge in ways that are sustainable and attuned to public concerns and issues. Initially, we briefly introduce and describe the precautionary principle and highlight its limitations for new technologies. We then conclude the section by reviewing several readings to the precautionary principle as proposed in several literatures. The section that follows, "Risk and Uncertainty Studies" outlines one of our project goals and research tasks.

The ascendance of the precautionary principle: Reaction to market-controlled technologies

Who controls risk and uncertainty in the toxicology of nanoparticles debate? On some level, the processes involved in learning about the human and environmental toxicology of nanoparticles and compounds substantially influence the rate of data flow. Methodologies are rigorous if findings are to be expected to contribute to the corpus of information about particles and compounds - and rightly so. Nonetheless, there remains disagreement. For example, there remains significant incoherence as to what characteristics of nanoparticles are most troublesome, e.g., charge, chirality, etc. though we have new data on this. Recent data we collected using a Delphi series involved experts from five subdisciplines and found a high level of concordance among respondents regarding the characteristics of nanoparticles perceived as being especially problematic. There was no priming involved in this research. The expert sample both introduced and ranked fourteen characteristics of nanoparticles and ranked in this order the top five characteristics deemed problematic were: reactivity, size, composition, surface area to volume, and surface charge. Information like this could be instrumental in establishing banding strategies to regulate nanoparticles. The same survey found concordance that carbon nanotubes were the most likely problematic of the nanoparticles species. Other species included quantum dots, metal oxides, metals, fullerenes, and polymers. In the metal oxide subcategory, zinc and silver ranked in the top two over titanium, cerium, and iron. The findings generated by PCOST and funded the NSF (#0809470) will be published soon. However, social science research of this nature has been lacking.

Furthermore, as the field gains the interest of many (contradictory) advocates, certainty and practical risk assessments take on more problematic roles. While academia may attempt to predict what particles and compounds will be most relevant in the next few years, academic researchers are wholly dependent on the actions of industry and the media who report on this issue. Nanoparticles are not simply patented as entities but also as the processes involved in their production. In addition, patents can be filed for how particles are integrated into product lines. Confidential business information severely restricts what information is in both the expert and inexpert spheres about nanoparticles used in marketable products. Industry controls certainty on another level. They not only know what is coming to market but also what in-house research may have to say about the EHS footprint of their products.

Finally, government regulators simply do not have the resources to critically examine all products coming onto the market. They do not have the power to control the opacity generated by current patent laws. In addition, regulators do not have the legislative power to demand screening of all products before they are marketed. As a result, society

is left with an approach, much like laissez-faire, whereby the market controls uncertainty and risk. This approach has the capacity to expose citizens to a potentially serious EHS footprint, especially given the record of a few “outlier” companies and corporations. This engendered fear has resulted in the ascendance of a serious consideration of the *precautionary principle* as the basis for a response.

The precautionary principle & emerging technologies

The “precautionary principle” has a distinguished history in Europe. Tickner and colleagues reference a 1992 United Nations Conference on Environment and Development, also known as Agenda 21 and trace the principle to its origin in the *Vorsorgeprinzip* that developed in the early 1970s into a fundamental principle of German environmental law. It is “the belief that society should seek to avoid environmental damage by careful forward planning, blocking the flow of potentially harmful activities” (Tickner, Raffensperger & Myers 2001, p. 2).

Tickner, Raffensperger and Myers attempted to justify a precautionary principle as a decision making and action tool to overcome proof burdens associated with formal scientific arguments. While precautionary principle language can be found in many international environmental agreements, it is mostly absent from environmental legislation in the USA and there have been many recent cases where the USA has lobbied against the principle.

One of the problems with the precautionary principles has been its definition. There are weaker and stronger versions of precaution. “One can think of a spectrum of precautionary actions from weak (intensive studying of a problem) to strong (prohibiting or phasing out a specific activity)” (Tickner, Raffensperger & Myers 2001, p. 5). Indeed, the power of the principle may be its variability. For example, Tickner et al refer to pre-market and pre-activity testing and include it among a list of possible precautions ranging from individual initiatives through bans and phase-outs. However, most of the precautions discussed in the decision-making literature tend to be strong ones.

One way to assess the roles played by risk and uncertainty is to examine how they may play out in a real-world application. To that end, the next few pages examine responses to marketing products involving engineered nanoparticles. In each application, different values associated with risk and uncertainty leads to sometimes dramatically different solution sets. While the following does not review all possible risk-uncertainty composite scenarios, we intend to use scenario building exercises some of which were involved in the following cases to begin the process of delineating relevant variables in risk and uncertainty studies in our work.

High uncertainty, high risk: Strict regulation or moratoria

We have a very hard reading of the *precautionary principle* by the absolutists, mostly the ETC Group (Canada) and their call for an outright moratorium on nanoproducts until more is known (ETC Group, 2003). A set of similar absolutist claims has been made from Friends of the Earth in Australia regarding certain product lines: cosmetics and sunscreens involving nanoparticles (FOE-A, 2006) and nanofood (FOE-A, 2008). Other concerned parties have offered still other restrictions. For example, last year, the Soil Association, an organic farming consortium in the UK, called for denying its organic label to foods and other products using engineered nanoparticles. “The organization stressed

that its ban on the use of such materials particularly underlined beauty products, but also applied to food and textiles, stating that it was taking action against this hazardous, potentially toxic technology that poses a serious new threat to human health” (Pittman 2008). In addition, there is a variation to the ETC Group moratorium in the form of a modified moratorium, which would restrict the intentional release of nanoproducts into the ecosystem even those highly desirable, such as safer options to bromide fire retardants.

The general pattern of respondents is that any prohibition would create a sizable bureaucracy, it would likely be ineffective given research can be conducted with inconspicuous tools, and it would impact business and industry negatively. And so forth.

Some uncertainty, some risk: Voluntary stewardship

While it is unlikely a strong interpretation of the *precautionary principle* would serve as the basis for regulation, a weaker interpretation with self-designed safety guidelines and protocols might prove productive. After a prolonged debate, the US Environmental Protection Agency (EPA) in 2008 announced its Nanoscale Materials Stewardship Program (NMSP). Other countries and international organizations have engaged in similar activities.

In summary, the US program calls on the voluntary disclosure of engineered nanoscale materials and makes available resources for evaluating these materials. The program calls on manufacturers, importers, processors, and users of engineered nanoscale materials to report to EPA key information about these materials within six months. The agency will evaluate the information to help ensure the safe manufacture and use of these nanoscale materials. EPA will also work with manufacturers, importers, processors and users of nanoscale materials to develop test data to provide a scientific basis for assessing the hazards, exposures, and risks of nanoscale materials. The NMSP will complement and support EPA's new and existing chemical programs under the Toxic Substances Control Act (TSCA). The NMSP includes, but is not limited to, existing chemical nanoscale materials manufactured or imported for commercial purposes as defined by TSCA. EPA encourages manufacturers and importers of new chemical nanoscale materials, which are subject to TSCA reporting requirements prior to manufacture, as well as researchers to consider reporting under the NMSP. The NMSP will help provide a firmer, scientific foundation for regulatory decisions by encouraging the development of key scientific information and use of risk management practices in developing and commercializing nanoscale materials (EPA 2008). So far, DuPont has stepped forward (DuPont first... 2008).

Detractors claim the program's legislation is weak and ultimately unable to adequately assess the risks and hazards of nanotechnologies. They cite the reluctance of companies to step forward as grounds for diminished expectations.

Some uncertainty, low risk: Best/common/good practices

Researchers are already coming together to propose *best practices* for workers. The US Department of Health and Human Services Centers for Disease Control and Prevention's National Institute for Occupational Safety and Health (NIOSH) and a consortium of corporations and other stakeholders known as the International Council on

Nanotechnology (ICON) have taken the lead though more have begun to enter the process.

NIOSH, in 2005, announced a partnership with employers and others in conducting field studies to observe and assess occupational health and safety practices in facilities where nanotechnology processes and applications are used and in October of the same year posted "Approaches to Safe Nanotechnology," an interim, on-line NIOSH guidance document, and to create a worker exposure database (NIOSH 2005). It remains one of the predominant documents in the field of environmental health and safety.

In 2006, ICON contracted with a research team from the University of California at Santa Barbara to produce a current practices report. While the size and representativeness of the sample and its methodology may be reproachable, it represented one of the first times survey information was collected and disseminated (ICON 2006). Other reports include a survey by Yale University's Deanna Lekas (2006) on firms in Connecticut and New York (Lekas 2006) and another (2007) by the University of Massachusetts Lowell's John Lindberg and Margaret Quinn who surveys firms in the Massachusetts region (Lundberg & Quinn 2007). In 2008, ICON had been examining the practicality and functionality on a web-base Wikipedia on good practices and in 2009 the GoodNano Wiki was released. The utility of this resource remains untested. The recent deaths of three Chinese workers at a nanoparticle fabrication facility allegedly caused by inhalation of nanoparticles (Song et al 2009) suggest the issue of EHS safety is more complicated than sharing data.

Low uncertainty, low risk: Self-regulation

An entirely different approach, a form of self-regulation, describes what happened when scientists and engineers came together for an Asilomar conference on DNA research in the seventies. No such event has been called for nanotechnology per se, though experts meet in a multitude of forums and a case can be made that activities similar to what occurred at Asilomar occur regularly in the nanoworld already.

Here's a quick review of the original self-regulation Asilomar conferences associated with biotechnology. Scientists met informally in 1974 at the Gordon Research Conference near Monterey, CA and drafted a letter to the National Institute of Health and the National Academy of Science about biotechnological research. It was published in *Science*. It called upon researchers to avoid certain areas of study until more was known about its societal implications. A second letter to *Science* and *Nature* called for a moratorium on some experiments. In February 1975, scientists met again at the Asilomar Conference Center and developed detailed guidelines. On February 15, 2000, the 25th anniversary of Asilomar was celebrated at the Asilomar Conference Center. Sixty-seven biologists, scholars, lawyers, government officials and others gathered at this invitation-only event to converse about the current state of affairs involving regulation in genetic engineering and to consider what might lie ahead. This group included 11 of the 1975 conferees and was hosted by Alex Capron, a participant in the 1975 meeting.

In the end, Asilomar was groundbreaking. On some level, scientists decided to regulate themselves. "The guidelines not only allowed the research to resume but also helped persuade Congress that legislative restrictions were not needed that scientists could govern themselves" (Baringa 2000). These became the official government regulations

covering recombinant DNA research funded by the NIH. Many companies continue to voluntarily subject their work to NIH standards and review and some licensing agreements call for such voluntary compliance.

This variation of professional ethics or *soft law* from Asilomar helped foster a professional self-regulating culture in biotechnology. Environmental Defense and DuPont undertook one of the closest parallels in nanotechnology in 2006-2007 (Nanorisk Framework 2007). DuPont conducted three demonstration projects in order to evaluate the comprehensiveness, practicality, and flexibility of the Framework. DuPont tested the framework against three products: DuPont™ Light Stabilizer 210 (a surface-treated high-rutile phase titanium dioxide), carbon nanotubes, and nano-sized zero-valent iron. The three nanomaterials differed in terms of composition, structure, intended application, stage of development, and DuPont's role in the development, evaluation, or potential use of the material (Case Studies 2007).

Responses from the stakeholder community have been mostly negative. One critic found the partnership suspicious. It is “aimed at bestowing existing commercial nanotech products with a degree of legitimacy that they don't necessarily deserve. The partnership's unspoken goals seem to include DuPont's desire to limit its potential legal liabilities with Environmental Defense's infatuation with market-based measures” (Center for Media and Democracy 2006).

The above four scenario exercises demonstrate significantly different decisions made on the basis of perceived risk against a range of uncertainties. From moratoria to self-regulation, we notice how decision-making is impacted substantially by risk and uncertainty estimates. This construction demonstrates as values for these variables are adjusted against each other we can get very different solution sets. We feel we have much to learn from exercises such as this one and plan to investigate scenario exercises like these in our ongoing research. Our work starts with the same scientific data sets but rather than privileging expert data, we have noted in experts from a broad community of stakeholders engage other tools when assessing risk and uncertainty. Nonetheless, we are committed to value their interests and sensibilities even if they are not “scientific”.

Risk and Uncertainty Studies

The term “risk studies” is not used very often though there are centers and institutes at both the University of Maryland (<http://www.enre.umd.edu/ctrs/>) and UCSB (<http://www.crss.ucsb.edu/>) claiming to address risk studies. The UMD site is totally dedicated to technical risk assessment while the UCSB site is still under construction. Neither site seems overly concerned about uncertainty as a variable in risk studies.

The term “uncertainty studies” appear to be an oxymoron; nonetheless the term is used to describe a variety of studies in a multitude of fields (Bonatti 1984). The term appears in oil and gas exploration, accident and safety, fuzziness and soft computing to name a few.

Faber, in concluding a book-length study of risk and uncertainty in the implementation of a new organization-wide software system, argued that there are few useful methods for examining and characterizing what he called “stochastic social networks” (Faber 2007a, p. 170). In general, such work accepts the certainty of uncertainty, begins with the premise uncertainty does not prevent management and decision making, and attempts

to relate the magnitude of uncertainty (confidence) with assessment and probabilistic forecasting (Faber 2007b, Morgan & Henrion 1990). Such an approach also accepts the potential for randomness within and across human systems and it seeks to understand the influence random events, contacts, and even statements have on decision-making.

The importance of “uncertainty studies” was illustrated in Rechlow’s work while at the Duke University Center for Environmental Toxicology and Risk Analysis. Uncertainty in environmental decision-making does not mean inaction. We informally make use of awareness of uncertainty by hedging decisions away from large losses. This hedging can be made explicit and formalized using the methods of decision analysis (Reckhow 1992).

Zehr’s challenge for studies of scientific risk and uncertainty provides a useful frame for addressing these questions and, as such, is worth citing in full.

“Nonscientists can become more aware of how scientific uncertainties are constructed and how they can become authoritative claims in themselves. If non-scientists fail to become aware of the management of scientific uncertainty, they open themselves to manipulation by scientists and other groups and organizations that use science for their own benefit. This lack of awareness tips the balance of power further in the direction of those best able to represent and interpret these uncertainties—a potentially dangerous arrangement for issues, such as genetic engineering and global warming, that touch the lives of many people. Widespread awareness of how scientific uncertainties are managed helps demystify science and increase the amount of influence that the public can exercise over decisions that affect their lives” (Zehr 1999, pp. 18-19).

We want to take it to another level by identifying variables, which affect the construction of the variables in uncertainty. For example, it is axiomatic that cross-cultural encounters are affected by insufficient or incomplete information about practices and language. We have noticed parallel phenomena associated with communication between expert and inexpert audiences for they function like different cultures. Indeed, the expert world is an organizational culture (OC) of sorts. While an OC reflects interests associated with different identities which factor into uncertainties, they also include factors to increase certainty under specific conditions and contexts (Pacanowsky & O’Donnell-Trujillo 1992). While a case could be made the OC of the expert world may be as diverse as the inexpert world, it does not refute the observations that varied interests in the inexpert world can often be at odds with those in the expert world. The factors to reduce uncertainty in the expert world may simply not crossover to the inexpert world.

Research questions

We agree with Powell et al when they wrote: “Relatively few scholars have explored lay publics’ risk uncertainty perceptions per se, or what factors shape these perceptions” (Powell, Dunwoody, Griffin & Nuewirth 2007, p. 323). Or, as Recklow has argued,

“Estimates of uncertainty in predictions are not unlike the point estimates of predicted response. Like the point predictions, the uncertainty estimates contain information that can improve risk assessment and decision-making. A decision support system will not eliminate this

uncertainty nor will it change the fact that, due to uncertainty, some decisions will yield consequences other than those anticipated. It will, however, allow risk assessors and decision makers to use the uncertainty to structure the analysis and present the scientific inferences in an appropriate way. In the long run, that should improve environmental management and decision making” (Reckhow 1994, p. 18).

Consequently, we are proposing to address these research questions in the years ahead and welcome any colleagues who wish to join us.

- What variables are relevant in risk studies involving phenomena with varying levels of uncertainty? And its obverse; what variables are relevant in uncertainty studies involving phenomena with varying levels of risk? For example, how do knowing and not knowing (need to know) influence perceived uncertainty about the risks associated with nanoscience and other emerging technologies?
- Do different stakeholders perceive risk and uncertainty differently and what are the grounds for these perceptions? In addition, how can we identify situations when risk and uncertainty are being used as a tactical device for reasons other than reasonable environmental and health safety concerns?
- When has sufficient uncertainty been resolved to allow meaningful and responsive decision-making and how do decision makers respond in cases of varying degrees of risk and uncertainty?
- How can we design instructional content to facilitate cognitive and affective learning in varied instructional contexts and for multiple student audiences to improve disposition of decisions given variable levels or degrees of risk and uncertainty.

Conclusion

The penchant for calls for more and more research and moratoria as a response to what we do not know will not satisfy calls for better decision making per se because certainty is not necessarily about more and better data. Certainty involves a better understanding of how we can live in an uncertain world. In addition, we must be aware and suspicious of claims of uncertainty given the strategic use of uncertainty as a bulwark against change and a call for redistribution of wealth and resources to fund ongoing research into increasingly abstruse and esoteric studies of contemporary phenomena including but not limited to the toxicology of the artifacts of emerging science and technology.

To this end research in risk and uncertainty studies (RUS_t) may help us better understand how to position ourselves to make the best decisions we can under acceptable levels of uncertainty. Just as there is no ultimate certitude all we can expect from risk and uncertainty studies is more stable footing to create algorithms to determine when enough is enough to make a decision.

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References

- Adeola, F.O. (2000). Endangered community, enduring people: Toxic contamination, health, and adaptive responses in a local context. *Environment and Behavior* 32 (2): 209–49.
- Babrow, A.S. (1995). Communication and problematic integration: Milan Kundera's 'lost letters' in *The book of laughter and forgetting*. *Communication Monographs* 62: 284-300.
- Babrow, A.S. (2002). Communication and problematic integration: Understanding diverging probability and value, ambiguity, ambivalence, and impossibility. *Communication Theory* 2: 95-130.
- Babrow, A.S. & Kline, K.N. (2000). From 'reducing' or 'managing' uncertainty: Reconceptualizing the central challenge in breast self-exams. *Social Science and Medicine* 51: 1805-1816.
- Barinaga, M. (2000). Asilomar revisited: Lessons for today, *Science* 287, 5458 (March 3, 2000). http://www.biotech-info.net/asilomar_revisited.html (accessed on June 29, 2004).
- Berger, C.R. & Calabrese, R.J. (1975). Some explorations in initial interaction and beyond: Toward a developments theory of interpersonal communication. *Human Communication Research* 1: 99-112.
- Berube, D. (2006). *Nanohype: The Truth Behind the Nanotechnology Buzz*. Amherst, NY: Prometheus Press.
- Berube, D. (2008a). Rhetorical gamesmanship in the nano debates over sunscreens and nanoparticles. *Journal of Nanoparticle Research*. 23-37. DOI: 10.1007/s11051-008-9362-7
- Berube, D. (2008b). *Intuitive Toxicology: The Public Perception of Nanoscience*. In *Nanoethics: Emerging Debates*. F. Allhoff & P. Lin (Eds). London: Springer. 2008. 91-108.
- Bonatti, L. (1984). *Uncertainty: Studies in philosophy, economics and socio-political theory*. Amsterdam: John Benjamin Publishing.
- Bradac, J. (2001). Theory comparison: Uncertainty reduction, problematic integration, uncertainty management, and other curious constructs. *Journal of Communication*, September: 456-476.
- Brashers, D.E. (2001). Communication and uncertainty management. *Journal of Communication* 51(3): 477–97.
- Brashers, D.E. & Babrow, A.S. (1996). Theorizing communication and health. *Communication Studies* 47: 243-251.
- Brashers, D.E., Neidig, J.L., Haas, S.M., Dobbs, L.K., Cardillo, L.W. & Russell, J.A. (2000). Communication in the management of uncertainty: The case of persons living with HIV or AIDS. *Communication Monographs* 67: 63-84.

Brown, P. & Mikkelsen, E. (1990). No safe place: Toxic waste, leukemia, and community action. Berkeley, CA: University of California Press.

Brunsson, N. (1985). The irrational organization. Chichester, UK: Wiley.

Bush, J., Moffatt, S. & Dunn, C. (2001). Keeping the public informed? Public negotiation of air quality information. *Public Understanding of Science* 10: 213–29.

Case Studies. Nanorisk Framework. <http://nanoriskframework.org/page.cfm?tagID=1326> (accessed January 29, 2008).

Center for Media and Democracy. PR watch.org. (January 18, 2006). <http://www.prwatch.org/node/4273>. (accessed January 29, 2008).

Chen, S.J. & Hwang, C.L. (1992). Fuzzy multiple attribute decision-making: Methods and application. *Lecture notes in economics and mathematical systems*. Berlin: Verlag Springer.

Coleman, C. (1993). The influence of mass media and interpersonal communication on societal and personal risk judgments. *Communication Research* 20 (4): 611–28.

Corbin, R.W. (1980). Decisions that might not get made. In T. Wallsten (Ed.) *Cognitive processes in choice and decision-making*. Hillsdale, NJ: Erlbaum.

Davis, T.J. & Keller, P. (1997). Modeling uncertainty in natural resource analysis using fuzzy sets and Monte Carlo simulation slope stability prediction. *International Journal of Geographical Information Science*. 11,5: 409-434. DOI: 10.1080/136588197242239.

DuPont first to participate in EPA nano stewardship program. (2008). *Small Times*. January 31. http://www.smalltimes.com/display_article/318785/109/ARTCL/none/none/1/DuPont-first-to-participate-in-EPA-nano-stewardship-program/ (accessed February 17, 2008).

EPA: Pollution Prevention and Toxics. Nanoscale materials stewardship program. January 28, 2008. <http://epa.gov/oppt/nano/stewardship.htm> (accessed January 29, 2008).

ETC Group. (2003). The big down: From genomes to atoms. http://www.etcgroup.org/en/materials/publications.html?pub_id=171 (accessed August 19, 2009).

Faber, B. (2007a). *Discourse, technology & change*. London & New York: Continuum.

Faber, B. (2007b). Writing social change. In C. Bazerman (Ed.) *Handbook of writing research*. Mahwah NJ: Lawrence Erlbaum Associates.

Friedman, S.M., Dunwoody, S. and Rogers, C.L., Eds. (1999). *Communicating uncertainty: Media coverage of new and controversial science*. Mahwah, NJ: Lawrence Erlbaum Associates.

Friends of the Earth – Australia (2006). Nanomaterials sunscreens and cosmetics: Small ingredients, big risks. <http://nano.foe.org.au/node/125> (accessed August 19, 2009).

Friends of the Earth – Australia (2008). Out of the laboratory and onto our places: Nanotechnology in food and agriculture. <http://nano.foe.org.au/node/227> (accessed August 19, 2009).

Gigenrenzer, G. (2002). Reckoning with risk: Learning to live with uncertainty. London: Allen Lane.

Gilovich, T., Griffin, D. and Kahneman, D. (2002). Heuristics and biases: The psychology of intuitive judgment. Cambridge UP.

Halliday M.A.K. & Martin, J. (1993). Writing science: Literacy and discursive power. Pittsburgh: University of Pittsburgh Press

Hallman, W. K. and Wandersman, A. (1992). Attribution of responsibility and individual and collective coping with environmental threats. *Journal of Social Issues* 49 (4): 101–18.

Hansen, A. (1993). The mass media and environmental issues. New York: Leicester University Press.

Heyman, B., Henriksen, M. and Maughan, K. (1998). Probabilities and health risks: A qualitative approach. *Social Science & Medicine* 47: 1295–306.

Hornig Priest, S. (2001). A grain of truth: The media, the public, and biotechnology. New York: Rowman and Littlefield.

ICON. Best Practices (November 13, 2006). http://icon.rice.edu/projects.cfm?doc_id=4388 (accessed January 29, 2008).

Irwin, A. & Wynne, B. (1996). Misunderstanding science? The public reconstruction of science and technology. Cambridge: Cambridge University Press.

Jackson, S.E. & Dutton, J.E. (1988). Discerning threats and opportunities. *Administrative Science Quarterly* 33: 370-387.

Johnson, B.B. (2003). Further notes on public response to uncertainty in risks and science. *Risk Analysis* 23 (4): 781–9.

Kahneman, D. & Tversky, A. (1982). Variants of uncertainty. *Cognition* 11: 143–57.

Kahneman, D., Slovic, P., & Tversky, A. (1982). Judgment under uncertainty: Heuristics and biases. New York: Cambridge University Press,

Kasperson, R.E., Ortwin, R., Slovic, P., Brown, H., Emel, J., Goble, R. L., Kasperson, J.X., & Ratick, S.J. (1988). The social amplification of risk: A conceptual framework. *Risk Analysis* 8: 177-187

Korpan, C., Bisanz, L., Dukewich, T., Robinson, K., Bisanz, J., Thibodeau, M., Hubbard, K., & Leighton, J. 1994. Assessing scientific literacy: taxonomy for classifying questions and knowledge about scientific research. Technical Report Number 94-1. Edmonton AB: University of Alberta, Center for Research in Child Development. (ERIC Doc. Reproduction Service No. ED SE05-4604.

Kurzweil, R. (2005). The singularity is near: When humans transcend biology. NY: Viking.

Lekas, D. (2006). Nanotechnology startup concerns, information needs, and opportunities to proactively address environmental, health, and social issues. July 1, 2006. http://www.nanotechproject.org/publications/archive/nanotechnology_startup_concerns/ (accessed January 29, 2008).

Lipschitz, R. & Strauss, O. (1997). Coping with uncertainty: A naturalistic decision-making analysis. *Organizational Behavior and Human Decision Processes* 69:2, February: 149-163.

Lundberg, J. & Quinn, M. (2007). A survey of environmental, health and safety risk management information needs and practices among nanotechnology firms in the Massachusetts region. Project on Emerging Nanotechnologies: Research Brief. December 2007. http://www.nanotechproject.org/file_download/226 (accessed January 29, 2008).

March, J.G., & Olson, J.P. (1976). *Ambiguity and choice in organizations*. Bergen, Norway, Universitetsforlaget.

McCaskey, M.B. (1986). *The executive challenge: Managing change and ambiguity*. Harper Business;

Merry, U. (1985). *Coping with uncertainty: Insights from the new sciences of chaos, self-organization, and complexity*. Westport, CT: Praeger.

Mishel, M.H. (1990). Reconceptualization of uncertainty in illness theory. *Image: Journal of Nursing Scholarship* 22: 256-262.

Mitzburg, H., Raisinghani, D. & Théorêt, A. (1976). The Structure of unstructured decision processes. *Administrative Science Quarterly* 21: 2 (June): 246-275.

Morgan, M.G. & Henrion, M. (1990). *Uncertainty*. Cambridge UP.

Nanorisk Framework (2007). <http://www.nanoriskframework.com/page.cfm?tagID=1095> (accessed January 29, 2008).

NIOSH. Approaches to safe nanotechnology: An Information exchange with NIOSH. OCTOBER 2005. <http://www.cdc.gov/niosh/topics/nanotech/safenano/> (accessed January 29, 2008).

Orasanu, J. & Connolly, T. (1993). The re-invention of decision-making. In G.A. Klein, J. Orasanu, R. Calderwood, & C. Zambok (Eds.) *Decision-making in action: Models and methods*. Norwood, NJ: Albex Publishing: 3-20.

Pacanowsky, M. & O'Donnell-Trujillo, N. (1992). Communication and organizational cultures. *The Western Journal of Speech Communication* 46: 115-130.

Pitman, S. (2008). Soil Association says nanotech cannot be defined as organic. *Packwire.com*. (January 15, 2008) <http://www.packwire.com/news/ng.asp?n=82546-soil-association-nanotechnology-ban-labelling> (accessed January 29, 2008).

Powell, M., Dunwoody, S., Griffin, R. & Neuwirth, K. (2007). Exploring lay uncertainty about an environmental health risk. *Public Understanding of Science* 16: 323-343. DOI: 10.1177/0963662507074491.

Reckhow, K.H. (1994). Water quality simulation modeling and uncertainty analysis for risk assessment and decision-making. *Ecological Modeling* 72: 1-20.

Reckhow, K.H. (1992). The importance of scientific uncertainty in decision-making. *Environmental Management* 18, 2: 161-166.

Sitkin, S. & Weingart, L. (1995). Determinants of risky decision-making behavior: A test of the mediating role of risk perceptions and propensity. *The Academy of Management Journal* 38:6 December: 1573-1592.

Song, Y., Li, X & Du, X. (2009). Exposure to nanoparticles is related to pleural effusion, pulmonary fibrosis and granuloma. *European Respiratory Journal*, 34: 559-567

Thompson, J. (1967). *Organizations in action*. NY: McGraw-Hill.

Tickner, J., Raffensperger, C. & Myers, N. (2001). *The Precautionary principle in action: A handbook*, 1st Edition, <http://biotech-info.net/handbook.pdf> (accessed August 17, 2003).

Vande Kopple, W.J. (1998). Relative clauses in spectroscopic articles in the *Physical Review*, beginnings and 1980. *Written Communication* 15: 170-202.

Vande Kopple, W.J. (2002). From the dynamic style to the synoptic style in spectroscopic articles in the *Physical Review: Beginnings and 1980*. *Written Communication* 19: 227-65.

Wakker, P. (1993). Savage's axioms usually imply violation of strict stochastic dominance. *The Review of Economic Studies* 60:2. April. 487-494.

Zehr, S. (1999). Scientists' representation of uncertainty. In *communicating uncertainty: Media coverage of new and controversial sciences*. M. Friedman, S. Dunwoody, & C.L. Rogers, (eds.). Mahwah, NJ: Lawrence Erlbaum Assoc: 3-21.

Zimmerman, C., Bisanz, G., Bisanz, J., Klein, J., & Klein, P. 2001. Science at the supermarket: A comparison of what appears in the popular press, experts' advice to readers, and what students want to know. *Public Understanding of Science* 10: 37-58.

Narrative Ethics: A Style of Mentoring

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Abstract

The purpose of this paper is to bring three principles of social order and three mythic Ways of life to bear upon the problem of mentoring graduate students in science and engineering. The main challenges posed to this paper are conflicts, whether of cultural, disciplinary or psychological origin, between the preference a mentor might have for a Way or style of mentoring and the preferences any of his or her students may have for other Ways of being mentored. The rationale for this paper, then, is that these principles and Ways of life can be universalized over time and cultural space. The main opportunity afforded this paper is to address the American Competes Act by discussing such conflicts in mixed audiences of faculty and students.

Introduction

An engagement of ethics with science or engineering operates in either of three modes. In the cross-disciplinary mode the tools and methods of ethics are used to study some learned work of science or engineering or some situation involving scientists or engineers. The engagement in this mode is called applied ethics, and the learned disciplines known as research ethics and engineering ethics furnish such studies. In the multidisciplinary mode the tools and methods of ethics are comingled and interact with the tools and methods of science or engineering in the process of composing a learned work of, say, science, or conducting a situation in, say, engineering practice. The so-called Truck Problem (Broome 1996) and so-called micro-insertion techniques (Riley 2009) furnish examples of this mode of engagement. In these modes ethics remains a legacy of Athens by maintaining the centrality of the individual in its arguments and respecting a primacy of reason underlying its argumentation.

In the interdisciplinary mode, an engagement of ethics with science or engineering may begin in either the cross-disciplinary mode or the multidisciplinary mode, but ends after some violence is done to the nature of ethics or the nature of science or engineering. And this violence is no mere expedient to escape rigor. In the *Concrete Sumo* (Broome 1999) for example, the individual as moral agent is transcended by persons known in various cultures as the Tradition Keeper. This is done to address complex, novel and potentially lethal engineering situations which do not allow for reflective thought. "The enemy is at the gate," so the engineers say. In this mode, ethics is transformed into a legacy of the Roman Empire inasmuch as it maintains an authoritative centrality in its arguments and respects a primacy of the will underlying its argumentation.

The purposes of this paper are to universalize these legacies into three mythic Ways of life and to bring them to bear upon the problem of mentoring graduate students in science and engineering. The main challenges posed to this paper are conflicts, whether of cultural, disciplinary or psychological origin, between the preference a mentor might have for a Way or style of mentoring and the preferences any of his or her students may have for other Ways of being mentored. The main opportunity afforded this paper is to

address the American Competes Act by discussing such conflicts in mixed audiences of faculty and students. The focus is on narratives *qua* lanterns by which faculty and students might discover their own preferences as well as the preferences of others, and *qua* chart they can use to navigate these discoveries in the murky, deep, shark-infested waters of collaborative research.

Three Principles of Social Order

Zigong asked about government. The Master (Confucius) said, "The requisites of government are that there be sufficient food, sufficient military equipment, and the confidence of the people in their ruler." Zigong said, "If one had to dispense with one of those three, which should be given up first?" "The military equipment," said the Master. Zigong again asked, "If one had to dispense with one of the two remaining, which should be given up?" The Master answered, "Give up the food. From of old, death has always been the lot of men; but if the people have no faith in their rulers, they cannot stand."¹

Confucius' principal followers, Mencius and Xun Zi, differed radically on Zigong's last question. Mencius, believing that human beings are basically good, sided with food inasmuch as it is a popular need. Xun Zi, believing that human beings are basically bad, sided with the ruler's need for military equipment.

The three principles of social order laid down herein tell us that a society is held intact by (1) ordinary members who see their society serving their individual self interests, (2) leaders presiding over a common cause the members put higher than self interest, and (3) leaders commanding regulatory and defensive forces.

It is a simplification but hardly a gross one to identify the three widely recognized solutions (that is, nontheological and nonbiological solutions) to the problem of order with the three major thinkers who argued that a social contract was necessary to overcome a prior presocial and/or prepolitical state of nature. Hobbes' solution was coercive, Locke's stressed mutual self-interest, and the Rousseau of *The Social Contract* gave primacy to normative consensus.²

Among the great books on the self-interest principle of social order are Locke's *Second Treatise on Civil Government* and Marx's *Das Kapital*. On this principle, the masses of ordinary people will come together and seek to act in ways that hold their society intact insofar as they see it in their self-interests to do so. At bottom are the self-interests called primary needs: food, shelter, etc. John Rawls goes to the next level with primary goods. These are things that any rational person is presumed to want. Natural primary goods include health and vigor, intelligence and imagination. Social primary goods include self-respect (self-esteem), rights and liberties, powers and opportunities, income and wealth.³

Among the great books on the normative commitment, common cause or higher (then self) cause principle of order is *The Social Contract* by Jean Jacques Rousseau. Emile Durkheim and Talcott Parsons also emphasized consensus based on norms and values.

¹ Confucius, c. 5th century BC.

² Wrong, D.H. 1994. *The Problem of Order: What Unites and Divides Society*. New York, NY: The Free Press, p. 9.

³ Rawls, p. 62.

This is principle of order that binds individuals together in a quest serving ends they deem higher than individual self-interests. Examples include Christianity and democracy.

Among the great books on the force principle of social order are Hobbes' *Leviathan*, Machiavelli's *The Prince*, and Sun Tzu's *The Art of War*. This is the principle that human society can be maintained intact only by force, i.e., coercion of the members of a society by threat of force and actual physical force. It includes internal force *qua* police as well as external force *qua* military.

Three Mythic Ways of Life

*The Oberlin Horse*⁴

When the U.S. entered the first World War in 1917, 360,000 blacks, invigorated by their faith in democracy, put aside bitter memories of segregation and race violence and joined the fight for democracy. ... After the War black soldiers returned to the United States with pride and a new sense of themselves and of their place in the world. They had fought side by side with black soldiers from other parts of the world. They had won the respect of foreign nations for their bravery. They returned with the hope that the spirit of democracy that they had fought for in Europe would await them in the United States.

These were thrilling times for African Americans: the migration of blacks from the rural South to obtain better conditions in the North was made possible by the labor requirements of the War; the Harlem Renaissance was born, viz Duke Ellington, Lena Horne, Langston Hughes, ...; Marcus Garvey founded the Universal Negro Improvement Association (U.N.I.A.) in 1917, the National Association for the Advancement of Colored People (N.A.A.C.P.) having been founded only seven years earlier; and at the end of the War, Uncle Roy and Uncle Thornton returned from France to their family home in Dutch-country Pennsylvania.

They returned with the new spirit, which for them included visions of college education. They arrived home, however, only to find their parents dead and their eldest sister, Irene, custodian of the younger seven siblings and two of her own fatherless children.

How, then, would they reconcile their new spirit with their newly found family responsibilities and their old companion, poverty? Answer: Irene got the spirit.

Irene laid down the plan: "Tis better that we struggle on a while longer while you men go to college in the hope that you'll return with something that will inspire all of these children to do likewise, than to resign ourselves to lifetimes of mediocrity."

Some one of them had heard that there was a college in Ohio that would let blacks in. Harry, one of the younger boys, said he too wanted to go. So, off the three went to Oberlin, Ohio.

They took work there in Oberlin, Ohio, and saved their money for the College. Time passed slowly. Their enthusiasm ungratified and their savings far from their

⁴ Broome & Peirce, 1997.

tuition needs, they came up with a plan. They bought a horse. Pennyless now, they made an appointment with "the" Dean.

"You may state your business," the Dean said.

"Do you see that horse outside your window?," said Roy, the eldest.

"Yes," replied the Dean.

"Well, we've noticed that you don't offer a course in horseback riding here.

Considering the social backgrounds of many of your students, it would seem that such a course would be popular among them. To offer such a course would seem the proper thing to do, here," they all replied.

"That's a good idea! How much would you charge?"

"Tuition!"

Roy went on to graduate from Bucknell with a degree in engineering and became a registered professional (licensed) engineer in the State of Pennsylvania, perhaps the first black to do so. And he was the first of his race to become a member of the Engineer's Club of Philadelphia.

Thornton became a licensed big game hunting guide in Canada, ostensibly the first of his race to do so.

Harry graduated from Oberlin and eventually obtained the Ph.D. in sociology from Columbia, and served for more than twenty years as professor of sociology at Howard.

Irene served as matriarch of the family for more than three generations, dying peacefully in her sleep at the age of ninety one.

The family, in all of its generations since that "horse," has consisted mainly of college graduates, including professors, deans, MDs, etc.

*Tubby*⁵

Roy, Thornton and Harry failed in every attempt to get their cousin Tubby to go to college. So, they came up with another plan for him.

In those days, world champion prize fighters went on exhibition tours around the country. They would visit small towns, much as would a county fair or a circus, giving "one-rounders" with locals. Typically, a prize would be given to the local who could stay in the ring with the champion one round or so without being K.O.'d. The plan was to get Tubby in the ring with a champion.

Having seen world-class boxing in Europe and in some big U.S. cities, Roy and Thornton knew that Tubby had the skills of a champion. They knew that, given the chance, Tubby could prove himself, earning thus a place of honor among them. And they knew that the reigning champion in Tubby's weight class would give an exhibition soon up in Dutch country, PA.

The day of the exhibition came. It was hot that day. Tubby got into the ring. And Tubby K.O.'d the champion!

⁵ Broome & Peirce, 1997.

Tubby's left hook may yet be talked about in the barber shops and pool rooms of Bloomsburg, PA.

On the eve of the knock out, the whole family showed up on the front lawn and porch of Tubby's house to meet the champ and his seconds and manager, and to help Tubby pack. He was going on tour with the champ! Or, so everyone thought.

It was cool that evening when Tubby announced that he would respect his mother's wishes by staying at home. There was a cool breeze in the air when his mother stepped forward and said, "Boxing is a sin." There was a chill in the air when she bid the champion and everyone else gathered there that evening a good night.

In the period 1964-86 Noam Chomsky revolutionized linguistics with his idea that all human beings have the same capacity for the same grammatical rules underlying all languages, and that this capacity is in-born, i.e. "hard-wired," so to speak, in the brain from birth. In *Acts of Meaning* (1990) Jerome Semour Bruner suggested that human beings have a capacity for narrative that is hard-wired in the brain from birth. This is to say that humans have a "readiness for narrative," an inclination to order experience as a story and to think in storied terms.⁶ The cultural anthropologist Georges Dumézil observed a tripartite ideology deriving from the mythic narratives of early Indo-European peoples: priest, guaranteeing an administration based on law and moral stability; warrior, offering a protective and conquering force; and a producer of nourishment and enjoyment.⁷ Accordingly, the three principles of social order laid down above are scripted into myth, i.e. personified and cast as heroes in mythic stories, and played out in reality. In Egyptian antiquity subject, high priest and pharaoh played the Sacred Triad: Horus, Isis and Osiris. In the Roman classical era citizen, bishop and emperor played the Holy Trinity: God the Son, Spirit and Father.

Heroes of the self-interest principle are ordinary members of societies as opposed to leaders, and their pathways in life exhibit the universal traits of what is herein called the Popular Way. Its heroes include Horus, God the Son, Cordelia (Act I), Telemachus and Socrates. As told above in *The Oberlin Horse*, Harry was a hero in the Popular Way. The younger brother of Roy and Thornton, he would obey them and yet maintain his individuality—then and throughout his life. While a faculty member at Howard University he was known to be the first to leave the flag pole, gathering place of faculty having grievances with the President, and among the handful to arrive at the President's office with their grievances.

Heroes of the common higher cause principle are leaders of societies and their pathways exhibit the universal traits of what is herein called the Way of the High Priestess or Priestly Way. Its heroes include Isis, God the Holy Spirit, Penelope and Martin Luther King, Jr. Guinevere was a hero: at first, Priestly; at last, Popular. As told above in *The Oberlin Horse*, Irene was the icon of the family. She took charge of the extended family by, in mythic terms, killing her former self, namely, "mother of two," so as to become mother of all over the protests of her eldest child. Thus, as Penelope kept Ithaca intact while Odysseus was off on adventure, Irene kept her family intact amid adversity and prosperity while three of her brothers were off on adventure.

⁶ McAdams, 1999.

⁷ Glendenning, 1999.

Heroes of the force principle are also leaders of societies, but their pathways exhibit the universal traits of what is herein called the Way of the King or Regal Way. Its heroes include Osiris, God the Father, Cordelia (Act V), Parzival and Nelson Mandela. As told above in *The Oberlin Horse*, Roy was the Regal hero of the family: he answered the call to Oberlin, faced the dragons of failure and poverty but prevailed over them, and brought the boons of an education back home to share with everyone.⁸ He did not marry until the youngest in the family graduated from high school. As told above in *Tubby*, the antihero of Roy was his cousin Tubby.

Three Mentoring Styles

The German research university was characterized, in part, by its requirements for a doctoral dissertation. Specifically, the doctoral student was required to publish a scholarly paper. The courses he signed up for, and the segments of those courses he saw fit to attend, were his choice. He visited his advisor rarely. Today, in the USA, some academic advisors collaborate with their dissertation students mainly to agree on a research topic and funding opportunities, a course of study, rare visitations by the student to the professor, and consultation on publication preparation and submission. Accordingly, the advisor's pathway in this collaboration was in the Popular Way and the advisee's pathway, also the Popular Way, was played out as by Socrates.

In the monastic tradition, researchers were committed to do research in the service of God's will as handed down to them by their clerical superiors. Today, in the USA, some academic advisors follow a version of the monastic tradition with a cooperative style. Mentor and mentee work together, occasionally as equals. Accordingly, the advisor's pathway in this collaboration was in the Way of the Primary Mask and the advisee's pathway, also the Popular Way, was played out as by Telemachus.

In 1500 AD there were about 500 universities in Europe. The Italian universities were institutes of medicine, law, government, etc. The students were apprentices, more or less, of their professors. Today, in the USA, some academic advisors manage the day-to-day progress of the dissertations of their doctoral student advisees. Accordingly, the advisor's pathway in this collaboration was in the Regal Way and the advisee's pathway, also the Popular Way, was played out as by Wiglaf.

When the collaboration style of a research leader agrees with the collaboration inclinations of his or her collaborator, their collaboration may well prove to be a harmonious one. However, when these styles clash the collaboration is likely to result in disharmony. The student will accuse his Popular advisor of neglect, his Priestly professor of micro-management or his Regal professor a task master. Accordingly, he will judge his professor guilty of extraordinary unethical acts. The professor will retort with accusations, respectively of childish whining, pomposity and adolescent disrespect. If unresolved, the disharmony can exact casualties.

These styles may be personal preferences or cultural ways of life. In the latter case, the globalization process of diversifying cultures in research collaborations may serve to invite disharmony. However, inasmuch as accusations of moral causes of disharmony may not be justifiable, resolutions may be sought, but too often not found, in collegiality.

⁸ Campbell, 1973.

Mentoring Processes

The mentoring experience can take place in a single style as addressed above, or in a sequence of two or more styles. For example, when I started my dissertation my advisor put me into a master/apprentice style. Having a preference for the German research model, I asked, "When will my dissertation come to an end?" He replied, "Today I am the teacher and you are the student. This research will become *your* dissertation when you become the teacher and I become the student." That day came. The project met an impasse and he told me to transcend it by method of X. I suggested Y but he relented. I did both X and Y. After presenting them and demonstrating the superiority of X to Y he asked, "What should we do next?" From that point on I called the meetings and more or less lectured on my progress. The dissertation ended when I asked, "Where should we publish?" and he replied, "Anywhere you like."

Another process is also developmental.⁹ It consists in three phases. Called Tell, the first phase is a master/apprentice style in which the mentor engages the protégé with problems having only one right answer. Called the Sell, the second phase is a transition from the Tell to the third phase called Collaborate. Specifically, in the Sell the mentor engages the protégé with problems having situation-dependent answers. This stimulates the protégé to defend his choices even when they disagree with those of the mentor. In the Collaborate phase the mentor and protégé become "true partners and are much more equal or peers in feeling ownership and responsibility for monitoring task accomplishment." The last phase is called Delegate. More or less a German research model, this phase sees the mentor become "primarily a cheer leader and encourager of the protégé."

Mentoring Ethics

Greek

The good man, or expert human, is thus an ace rationalist, either in that his actions are as a rule soundly based on excellent reasoning, or in that he indulges fairly often in fine excogitations.¹⁰

The Greek tradition of ethics puts the individual above the state and, inasmuch as the passions can be controlled by the will, it puts reason above the will. This tradition consists in theory and applications of theory to cases, i.e. case studies.

The Cambridge Dictionary of Philosophy (Audi 1995) tells that "ethics, along with logic, metaphysics, and epistemology, is one of the main branches of philosophy," and it tells that "the general theory of goodness and the general theory of right action constitute the main business of ethics." Normative or prescriptive ethics is concerned with giving advice: it says what one should or ought to do and why; what one should not or ought not do and why. Descriptive ethics is concerned with analyses of situations for their ethical contents. The two main categories of ethical theories are deontological ethics and consequentialist ethics. In his *Critique of Practical Reason* (1788), Kant said a thing is good or an act is right if it coheres, according to rules of logic, with the appropriate principles. In his *Utilitarianism* (1863), John Stuart Mill said a thing is good or an act is

⁹ Sweeny, 2003.

¹⁰ Thomson ([1955] 1980)

right if it corresponds to facts, specifically, the maximization of pleasure among the affected parties. The purposes of this paper are served by treating other categories, namely, casuistic ethics, virtue ethics, and narrative ethics, in more detail.

Casuistic Ethics. Electrical engineers make devices that imitate thinking in the human brain. Called neural networks, these devices consist in hosts of microchips each processing electrical input signals into electrical output signals in much the same way brain neurons process electro-chemical signals. Let us say the device receives input from a computer screen and that its output is either a red blinking light or a green blinking light. The question for the engineer is: How shall I connect these chips together so that the green light blinks when a legitimate dollar bill is on the screen and the red light blinks when a counterfeit bill is on the screen? This is a design question. To answer it he assembles a stack of new and old bills. The old ones are crumpled, torn and stained bills. Some of the bills are real and the others counterfeit. He scans these bills into the computer as jpg files, and assembles the files into a folder. Then he connects the chips, say, randomly, brings up a picture of a bill on the screen, and reads device's output. He continues this process until he arrives at a design that produces a green blinking light for every real bill in the folder and a red blinking light for every counterfeit bill in the folder. The device is then said to be designed or trained. Then the device goes into the market. There a bill reader for a soda pop machine scans an unknown bill into its computer. Its neural network device in effect compares the bill with the bills on which it was trained and "decides" whether the bill is legitimate or counterfeit. Its decision is reported by its output to the soda pop machine's dispenser which, accordingly, dispenses soda or not. Metaphorically speaking, ethicists do the same thing:

"In accordance with the casuistic approach to ethics, you, the moral agent, ask: What are the paradigmatic cases that provide the outer boundaries for assessing Dr. X's erroneous publication? Is X's case more like a case of intentional wrongdoing, where the researcher has deliberately published false information for personal gain? Or is it more like a case of negligent oversight, where the researcher has failed to recheck the numbers in his or her data set carefully enough before submitting them for publication? If X's situation is closer to the former case, then it is clearly unethical. If it (is) more like the latter case, then it may be excusable and not even considered wrongdoing."¹¹

This approach is particularly suited to case studies. Just as the folder of jpg files served the engineer as a training set for the device, the above paradigmatic cases served "you" as the training set for the casuistic approach. Just as a user used the device to make a decision about how to treat an unknown bill, "you" came to a decision about Dr. X by comparing X's case to the paradigms. And you came to that decision rationally.

Virtue Ethics. The virtue ethicist seeks to do three things. First is to name and justify a complete portfolio of virtues, i.e. character traits which endow an individual with the gift of ethical reasoning and action without resort to ethical theory. For Plato the virtues are wisdom, courage, temperance and justice; for Aristotle, habits leading to the choice of the mean between extremes in conduct; for St. Paul they were faith, hope and charity. Second, the virtue ethicist seeks a person, whether living, historical or mythical, who is so endowed. For Plato, Socrates was a virtuous person. For St. Paul, Jesus was a virtuous or righteous person. For Westerners, Parzifal was a virtuous or chivalrous

¹¹ Penslar, 1995, p. 21.

person. Third and finally, the virtue ethicist seeks to substitute a virtuous person for an ordinary person playing a role in a real situation, speculate how the virtuous person would act out that role, and then advise the ordinary person to act likewise. Catholics have *Imitatio Christi*¹² which advises one to get to know Jesus through the Bible and do as he would do were he in one's own situation.

Narrative Ethics. In psychology, personality can be discussed in terms of five principles together defining personality as "(a) an individual's unique variation on the general evolutionary design for human nature, expressed as a developing pattern of (b) dispositional traits, (c) characteristic adaptations, and (d) self-defining life narratives, complexly and differentially situated (e) in culture and social context."¹³ According to the fourth principle, narrative identity is "an internalized and evolving narrative of the self that incorporates the reconstructed past and imagined future into a more or less coherent whole in order to provide the person's life with some degree of unity, purpose, and meaning."¹⁴ And according to the fifth principle, culture influences life stories by "providing a menu of themes, images, and plots for the psychosocial construction of narrative identity."¹⁵ In the clinical situation, a patient articulates a problem to his psychologist who responds by helping the patient construct his narrative identity.¹⁶ Aware of the power stories have to capture something of the unconscious, the psychologist distills from the story a clarification of the problem and uses it to help the patient solve the problem.¹⁷ In ethics, the ethicist likewise uses narrative self identities to advise people, but to advise them on their ethical problems. He examines the narrative for traits of mythic stories telling of pathways in life taken by mythic heroes.¹⁸ He may then tell the advisee, "You are you a hero," or ask, "Do you wish to be a hero? Should you be a hero? Why?" If the hero is justifiably said to be an individual with the gift of ethical reasoning and action without resort to ethical theory, yes answers to these questions would lead to a kind of virtue ethics. If the action taken by the advisee follows the pathway of that hero, and if that pathway is proximal to pathways known to be good or right, that action would be considered casuistic.

Roman

The Romans were more interested in practical matters of law, governance, and military strategy, than they were in philosophy and art. But for Cicero, to really use philosophy effectively, he needed to make it accessible to a Roman audience. He did this in part by translating Greek works into Latin, including inventing Latin words where none seemed suitable for Greek concepts (including the Latin words which give us the English words morals, property, individual, science, image, and appetite)...He placed politics above philosophical study; the latter was valuable in its own right but was even more valuable as the means to more effective political action."¹⁹

The Roman tradition of ethics or morals puts the state above the individual and, inasmuch as practical necessities require the will, it puts the will above reason.

¹² Downey, 1993.

¹³ McAdams, 2006, p. 204

¹⁴ McAdams, 2006, p. 209-210

¹⁵ McAdams, 2006, p. 211

¹⁶ McAdams, 1999.

¹⁷ Winston, et al., 2005.

¹⁸ Broome, 1996.

¹⁹ <http://www.iep.utm.edu/c/cicero.htm> [July, 2006]

The Roman secular academic worldview speaks of morals and ethics in reference to law and professional conduct. Christian ethics is a Roman Non-secular academic worldview albeit one that borrows heavily from the Greek academic worldview. Although many of the professions have adopted so-called codes of ethics, these codes are not Greek academic worldviews but Roman secular academic worldviews. Likewise, in the USA the Ethics in Government Law and the various ethical regulations and standards of the academic research funding agencies, e.g. the National Science Foundation (NSF), the National Institutes of Health (NIH), the US Department of Defense (DoD), are Roman secular academic worldviews.

Insofar as ethics is concerned, the Roman secular academic worldview operates on student codes of conduct, faculty codes of ethics, the conduct of research, and so on. The Roman non-secular academic worldview operates in the curricula of the schools of religion. The university Chaplain and Chapel fall under administration and are therefore regulated by the Roman secular academic worldview, which allows the Roman non-secular worldview to operate there on religious guidance but not on religious instruction or religious missionary activities. The Greek academic worldview operates in the curricula of the other schools and colleges as well as in the informal, mostly private processes of academic mentoring. It operates in five modes: deontological ethics; consequentialist ethics; casuistic ethics; virtue ethics; and of late narrative ethics.

Research ethics is the application of ethics to the conduct of research projects. The bulk of the discussions on research ethics have to do with research in science, particularly the physical sciences. The bulk of the discussions in engineering ethics, business ethics and legal ethics are not about research but professional practice. In the USA, scientific research accounts for most of the funded research activity in universities and the federal government including the military. Some of that activity has and continues to be sensationalized by the press, the most recent outrage being the anthrax case at Fort Detrick, Maryland (USA). Some of the concepts normally associated with but hardly limited to research ethics in science are considered misconduct in science.

“Misconduct in science is fabrication, falsification, or plagiarism, in proposing, performing, or reporting research. Fabrication is making up data or results. Falsification is changing data or results. Plagiarism is using the ideas or words of another person without giving appropriate credit.”²⁰ Misconduct in science does not include errors of judgment; errors in the recording, selection, or analysis of data; differences of opinions involving the interpretation of data; or misconduct unrelated to the research process. In 1979 *The Belmont Report: Ethical Principles and Guidelines for the Protection of Human Subjects of Research* said:

“Informing subjects of some pertinent aspect of the research is likely to impair the validity of the research. In many cases, it is sufficient to indicate to subjects that they are being invited to participate in research of which some features will not be revealed until the research is concluded. Such research is justified only if it is clear the 1) incomplete disclosure is truly necessary to accomplish the goals of the research, 2) undisclosed risks to subjects are no more than minimal, and 3) there is an adequate plan for debriefing subjects, when appropriate, and for dissemination of results to them.”²¹

²⁰ _____, *Responsible Science*, p. 27. The original language of misconduct in science included “other serious deviations from accepted research practices,” but this language has and remains rejected by the scientific community by reason of ambiguity.

²¹ _____, *Belmont Report*, p. 6.

Nevertheless, there are long-term consequences of deceptive research:

“A shocking incident at the Seattle campus of the University of Washington in 1973 illustrates one danger of such widespread awareness of deceptive research methods in psychology. Students on their way to class witnessed a shooting and neither stopped to help the victim nor followed the assailant; when questioned later, some witnesses reported that they thought the incident was a psychology experiment!”²²

Non-Western

It is said that, in ancient Athens, a philosopher known as a Stoic was lecturing in a village square to the local citizenry when one among his audience asked, smugly, “Why should I be reasonable?” The Stoic replied, “Do you want a reasonable answer?” For twenty-four centuries, this story has justified rationalism to the most belligerent of students. However, in practical situations where the enemy is at the gates, so to speak, i.e. where rationalism requires meditation but time is short, the stakes are high, i.e. lethal, and where the situation is novel,²³ something has to be done.²⁴ Doing the best that one can do rationally has never been the answer.²⁵ The following demonstrates what can be done:

*The Concrete Sumo*²⁶

The ink on my engineering diploma was but three weeks dry that early morning in the summer of 1966.

I had taken a job as a field engineer with a construction outfit, and was assigned to a site. I reported there that early morning clad in starched khaki shirt and pants, spit-shined ROTC boots, hard hat, and slide rule at the ready. As I arrived, the workmen, who were waiting in small groups at the entrance of the site for the whistle to blow, dressed me up and down, and immediately directed me to “the trailer.” They knew, somehow, that this was my first day as a real engineer. When I opened the door of the trailer, three important-looking chaps greeted me on their way out. First to greet me was the old superintendent, a walking example of dignity and wisdom. He wore a floppy hat of the Indiana Jones variety, puffed on a pipe, and apologized for leaving. It seemed that there was a failure on some other of the company's jobs across town that required his attention.

Second was the project manager, a younger version of the superintendent, but without the pipe, who clutched some important-looking drawings. He also apologized for leaving. Apparently there were some discrepancies between what was in the “hole” and what City Hall records said couldn't be there.

Finally, the carpenter foreman said “hello,” then disappeared down into the hole.

The whistle blew, everybody else and every machine got busy. I stayed in the trailer, made a cup of awful coffee, propped my feet upon a table, and began to

²² Schrag, 1997, p. 75.

²³ Broome, 1985.

²⁴ Ferguson, 1979.

²⁵ Fischbein, 1987.

²⁶ Broome & Peirce, 1997.

fantasize about what it would be like to know what I should be doing. Then it happened.

He looked to me at the time like a sumo wrestler with a bad attitude. I couldn't even tell which end of the cigar in his mouth was lit. And he exhibited the aura of a man who had no regard for rookie field engineers. He produced a wad of what he called "trip tickets," ordered me to sign one of them, then demanded directions from me indicating where to pour the concrete that was churning inside the fleet of trucks he had waiting outside the trailer.

I politely informed him that this was my first day on the job and that my bosses were away, and suggested that he take the concrete back. As the last part of that suggestion came out of my mouth, I came to realize that my career and physical well-being lay in peril.

Pointing to the signed trip tickets, he said that his duty was to deliver concrete to this site. Pointing to the trucks, he said that he would either pour the concrete where I so directed, or that he would dump the concrete where the trucks stood. Pointing into my face, he said that this choice was my problem. Then he looked at his watch, mumbling something about concrete setting-up in his trucks and a delivery schedule. I said to him that I would have my decision presently.

In the Johnny-on-the-Spot, Hamlet was the first to speak to me: "No court in the land," he said, "would blame you for letting the sumo dump the concrete in the entrance way. It's not your fault that they left you alone on your first day!" Then, Roebling began to speak: "You are an engineer, and engineers sacrifice all for their responsibilities to the business of engineering!" Finally, Uncle Roy, the engineer after whom I had patterned my career, spoke to me: "This job belongs as much to you as to anyone else. So, you have a duty either to move this project along, or resign!"

When I returned to the trailer from the Johnny-on-the-Spot, my nerves were in tact and I had conjured up a do-or-die attitude about the situation. I noticed the critical path schedule on the wall of the trailer and engaged it. The day's tasks were revealed, and among them was scribbled "pour elevator pit." On the table that dominated the furnishings of the trailer were some blue prints, and one of them clearly indicated the specifications for the elevator pit.

When oriented to North, the blue print showed the location of the pit in the hole. I looked down into the hole only to see the carpenter foreman sitting on the elevator pit, waiting. I called out to him, "Are the forms for the elevator pit ready to pour?" Agitated, he responded in the affirmative. Filled with courage, I then confronted the concrete "sumo" with my orders: "Pour that elevator pit!"

Upon returning to the job at the end of the day, the superintendent and the project manager made haste to the elevator pit, inspected it with much discussion, then came up to the trailer. They asked me how my day had gone, and I gave them a casual "O.K." I couldn't give them the satisfaction of knowing that the trouble they'd invented for me brought on any panic.

My last day on the job was occasioned by my acceptance to graduate school, and by lunch treated me by the superintendent and the project manager. We exchanged pleasantries before I recalled for them the elevator pit task left to me on my first day. I expected the superintendent to say that the carpenter foreman was alerted to the plot and instructed to prevent any catastrophe. Instead, he recalled for me that on his first day he was likewise abandoned and thus laid out a church, not only in the wrong direction, but also on the wrong lot! Without any apology at all he said: "When it comes to rookie engineers, it is better to pay early, than to pay later."

At first blush, this solution would seem a case of virtue ethics. Upon closer inspection, however, the use of Roy cannot be justified rationally. Nonetheless, inasmuch as Roy is a Regal hero in the engineering tradition, I could have expected to keep my job if things had gone wrong. There was no possibility of keeping it had I followed Tubby.²⁷

Roy is also a hero in the non-Western traditions of the Tradition Keepers in Nigeria, Estonia, and elsewhere in the world. Why is has this tradition not been passed down in the Roman legacy of morals?

One of the most astonishing features of the Roman Empire is the sheer diversity of the geographical and cultural landscapes it controlled. It was a European empire in the sense that it controlled most of the territory of the member states of the present EU, except part of Germany and Scandinavia. But it was above all a Mediterranean empire, and pulled together diverse cultures, in Asia (the Near East), Egypt and North Africa that have not been reunited since the spread of Islam. This represented a vast diversity, including language (two 'international' languages were still needed for communication, Greek as well as Latin, let alone local languages)...²⁸

The diversity of mythic heroes in the Roman Empire blurs its mythic legacies. Roman law was imposed on everybody and Constantine the Great made Christianity the state religion of the Roman Empire, but engineering traditions were continually blended by reason of cultural diversity and the impulse of progress.

Does this case suggest a new kind of ethics, or a new scholarly discipline existing alongside Greek ethics and Roman morals?

Mentoring Narrative Nanotechnology Ethics

Societal and ethical implications of nanotechnology have become a hot topic of public debates in many countries because both revolutionary changes and strong public concerns are expected from its development. Because nanotechnology is, at this point, mostly articulated in visionary and futuristic terms, it is difficult to apply standard methods of technology assessment and even more difficult to consider it in engineering ethics courses. In this article, the authors suggest using selected science fiction stories in the engineering ethics classroom to provide students with ethical skills and cultural knowledge required for engaging in public debates and for responsible decision making. Against the background of general

²⁷ Broome, 1999.

²⁸ Wallace-Hadrill, 2001.

debates on teaching engineering ethics, they do so by discussing the advantages and possible drawbacks of this approach and by presenting two examples of nano-science fiction classics.²⁹

In Michael Crichton's *Prey*, a corporation has created a self-replicating swarm of nanotech machines. The swarm was designed to be a military eye in the sky, but has now escaped into the environment and is killing people. Here, then, is a hypothetical case for ethical study. A narrative, the study is not an instance of narrative ethics. However, substitution of Roy for the main character and playing out the rest of the story accordingly would constitute an instance of narrative ethics in a non-Western tradition.

Summary & Conclusions

This paper brought three principles of social order and three mythic Ways of life to bear upon the problem of mentoring graduate students in science and engineering. The result is a non-Western genre of narrative ethics applied to science fiction stories having nanotechnology themes. The main challenges posed to this paper were conflicts, whether of cultural, disciplinary or psychological origin, between the preference a mentor might have for a Way or style of mentoring and the preferences any of his or her dissertation students may have for other Ways of being mentored. These challenges were met by offering cultural and temporal universals to discussions about mentor/mentee relationships. The main opportunity afforded this paper was to address the American Competes Act by presenting such conflicts to mixed audiences of faculty and students.

²⁹ Berne and Schummer, 2005.

References

_____. 1979. *The Belmont Report: Ethical Principles and Guidelines for the Protection of Human Subjects of Research*. The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, April 18, 1979, US Department of Health, Education and Welfare (Now, US Department of Health and Human Services).

_____. 1993. *Responsible Science: Ensuring the Integrity of the Research Process*. Washington, DC: National Academy Press, Volume I.

_____. 1993. *Responsible Science: Ensuring the Integrity of the Research Process*. Washington, DC: National Academy Press, Volume II.

Audi, R. gen. ed. 1995. *The Cambridge of Philosophy*. Cambridge, UK: The Cambridge University Press.

Berne, R.W. and Schummer, J. 2005. Teaching Societal and Ethical Implications of Nanotechnology to Engineering Students Through Science Fiction. *Bulletin of Science, Technology & Society*, vol. 25, no. 6, pp. 459-468.

Broome, T.H. 1985. Engineering the Philosophy of Science. *Metaphilosophy*, vol. 16, no. 1, pp. 47-56.

Broome, T.H. 1996. The Heroic Mentorship. *Science Communication: An Interdisciplinary Journal of the Social Sciences*, vol. 17, no. 4, pp. 398-429—June.

Broome, T.H. and Peirce, J. 1997. The Heroic Engineer. *J. of Engineering Education*, vol. 86, no. 1, pp. 51-55.—January.

Broome, T.H. 1999. Case Study: The Concrete Sumo. *Science and Engineering Ethics*, vol. 5, issue 4, pp. 542-547. This paper, its Commentaries, and Broome's Reply are introduced by Pritchard, M. p. 541. Commentaries: Weil, V., Understanding the "Concrete Sumo," pp. 548-549; Pritchard, M., Broome's "Concrete Sumo," pp. 550- 553; Herkert, J., Concrete Ethics, pp. 554-555; Davis, M., Wrestling With Broome's Concrete Sumo, pp. 556-564. Broome, TH., Reply to Commentaries, pp. 565-567.

Bruner, J.S. 1990. *Acts of Meaning*. Cambridge, MA: President and Fellows of Harvard College.

Campbell, J. 1973. *The Hero With a Thousand Faces*. Princeton, NJ: Princeton University Press.

Confucius, c. 5th century BC. "On Government," *Analects*.

Crichton, M. 2003. *Prey*. New York, NY: Harper Collins.

Downey, M., ed. 1993. *The Dictionary of Catholic Spirituality*. Collegeville, MN: The Liturgical Press, p. 163.

Glendinning, S, ed. 1999. *The Edinburgh Encyclopedia of Continental Philosophy*. New York, NY: Routledge, pp. 561-563.

Ferguson, E. 1979. Imperatives of Engineering. In Burke, J., et al. *Connections: Technology and Change*. San Francisco, CA: Boyd and Fraser, pp. 30-31.

Fischbein, E. 1987. *Intuition in Science and Mathematics: An Educational Approach*. Boston, MA: D. Reidel Publishing Company.

McAdams, D.P. 1999. Personal narratives and the life story. In L. A. Pervin & O. P. John (Eds.), *Handbook of personality: Theory and research* (2nd ed., pp. 478-500). New York/London: The Guilford Press.

McAdams, D.P. 2006. A New Big Five. *American Psychologist*, Vol. 61, No. 3, pp. 204-217.

Penslar, R. 1995. *Research Ethics: Case & Materials*. Bloomington, IN: Indiana University Press.

Rawls, J. 1971. *A Theory of Justice*. Cambridge, MA: Harvard University Press.

Riley, K.; Davis, M.; Cox, A.; Maciukenas, J. PIs, (2009) "Ethics in the Details": An NSF Project to Integrate Ethics into the Graduate Engineering Curriculum.

Schrag, B., ed. 1997. *Research Ethics: Fifteen Cases and Commentaries*. Bloomington, IN: Association for Practical and Professional Ethics, vol. I.

Sweeny, B. 2003. *The Four Styles Mentoring Process*. <http://www.mentoring-association.org/MembersOnly/Process/4StyleMprocess.html>.

Thomson, J.A.K., Tredennick, H. and Barnes, J. ([1955] 1980) *The Ethics of Aristotle*. New York, NY: Penguin Books.

Wallace-Hadrill, A. 2001. *Roman Empire: The Paradox of Power*. BBC.

Winston, C. E., & Kittles, R. A. 2005. Psychological and ethical issues related to identity and inferring ancestry of African Americans. In T. R. Turner (Ed.), *Biological anthropology and ethics: From repatriation to genetic identity* (pp. 209-230). Albany, NY: State University of New York Press.

Wrong, D.H. 1994. *The Problem of Order: What Unites and Divides Society*. New York, NY: The Free Press, p. 9.

The Roots, Branches and First Fruits of the Anticipatory Governance of Nanotechnologies

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Introduction, or Polanyi's Folly

Michael Polanyi's essay, "The Republic of Science," is a touchstone of sorts for me. I find it admirably learned and maddeningly wrong, but both in so many of the right ways that I can't help but come back to it time and again for the proof of my own analysis or arguments. Originally published in the journal *Minerva*, under the sharp eye and green felt-tipped pen of Edward Shils, the essay has been reprinted numerous times, including in the magnificent collection, *Criteria for Scientific Development: Public Policy and National Goals* (Shils 1968), with essays by Alvin Weinberg, John Maddox, Stephen Toulmin, and others whose understandings of science and science policy we've inherited even without, now more than two score years later, recalling their names or their work.

In his essay, Polanyi weaves an intricate analogy between the conduct of scientific research and the play of the economic market. Both are, in his view, examples of the way in which individuals can maximize socially beneficial outcomes by pursuing their own interests and adjusting, mutually but independently, to the interests of others. In other words, the same "invisible hand" that guides the market guides science. The implication of course is that science as an autonomous, self-governing and self-correcting enterprise should be left alone by government. The playing out of the market analogy is the "political and economic theory" of the essay's subtitle.

As I have described elsewhere (Guston 2000: 66-69), Polanyi is not alone in staking an analysis to an analogy between science and market. From Max Weber to Robert Merton to Bruno Latour and Steve Woolgar, social scientists have looked at the market and also seen an image of science, or vice versa.² And it is perhaps a delicious irony that Michael Polanyi's own brother, Karl, an economist, authored a provocative inquiry into what might best be called the political construction of the market, demonstrating that what we might now perceive as autonomous, self-governing and self-correcting was the self-conscious creation of policies that reconfigured farms and people, respectively, into the commodities of land and labor (Polanyi 1956).

A keystone of Michael Polanyi's argument for autonomous science is the essential unpredictability of scientific advance and any technical and societal outcomes dependent upon it, and thus that intentionally guiding research toward any specified human end is doomed to fail. In his own words, "I appreciate the generous sentiments which actuate the aspiration of guiding the progress of science into socially beneficent channels, but I

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² In *The Protestant Ethic*, Weber (2002 [1905]) assures readers in a footnote that all that he argues for with respect to capitalism is true for science. Merton (1938) demonstrates Weber's supposition. Latour and Woolgar (1979) focus more on the micro-economic exchanges of science in which credibility cycles through multiple exchanges like currency.

hold its aim to be impossible and nonsensical” (Polanyi 1968 [1962]: 9). Indeed, note the attachment of affective language (“generous sentiments”) to the aim of guiding science, and of dispassionate language (“impossible and nonsensical”) to its dismissal.

In defense of this claim, Polanyi tells the following anecdote, which I will quote extensively because of its interest here:

In January 1945 [Bertrand] Lord Russell and I were together on the BBC Brains Trust. We were asked about the possible technical uses of Einstein’s theory of relativity, and neither of us could think of any. This was 40 years after the publication of the theory and 50 years after the inception by Einstein of the work which led to its discovery....But, actually, the technical application of relativity, which neither Russell nor I could think of, was to be revealed within a few months by the explosion of the first atomic bomb....

Perhaps Russell and I should have done better in foreseeing these applications of relativity in January 1945, but it is obvious that Einstein could not possibly take these future consequences into account when he started on the problem which led to the discovery of relativity at the turn of the century. For one thing, another dozen or more discoveries had yet to be made before relativity could be combined with them to yield the technical progress which opened the atomic age.

Any attempt at guiding scientific research towards a purpose other than its own is an attempt to deflect it from the advancement of science....You can kill or mutilate the advance of science, you cannot shape it. For it can advance only by essentially unpredictable steps, pursuing problems of its own, and the practical benefits of these advances will be incidental and hence doubly unpredictable.

One might have some sympathy for Polanyi and Russell in their rather public failure on the most popular British radio show of its day.³ But perhaps they could have done better indeed. After all, *people were* working on the bomb in January 1945 because they realized the connection between mass and energy – even if they were laboring in secret, highly compartmentalized districts across the United States. And in order to have begun the project, someone must have initially seized upon this connection. In the popular version, this is Leo Szilard, who in 1939 contacted Einstein to write the letter about the possibility of a bomb to President Franklin Roosevelt.

But the point I wish to explore in this paper is not whether two of the most highly regarded intellectuals of their day – Polanyi and Russell, both polymaths, both fellows of the Royal Society, the latter a future Nobel laureate and the former the father of one to be – sitting in a BBC radio booth and queried by a disembodied voice, should have foreseen the social and technical consequences, nearly upon them, of a decades-old contribution in a field closely related to their expertises. Rather, I wish to explore three points: first, is there a more reasonable expectation to have of the capacity of foresight than simply saying, “I’m smart, and I didn’t think of it, and so it cannot be thought of!”? Second, what is the relationship between any such more reasonable expectation and

³ I am attempting to retrieve from the BBC a transcript or sound clip of the show, but as of this writing I have been unable to do so.

our responsibilities as scientists, social scientists, and citizens to “take these future consequences into account” when we work on a scientific problem? And third, what kind of research, education, and outreach programs might help fulfill these responsibilities? The remainder of this essay attempts to respond to these questions.

What to Expect of Foresight, or Polanyi’s Dilemma

While our ability to judge Polanyi and Russell may be 20/20 in hindsight, another historical example offered by political scientist and activist Richard Sclove suggests more provocatively the kind of vision that is necessary for accurate foresight. Sclove (1989: 163-64) tells a remarkable story about the atomic bomb to juxtapose with Polanyi’s:

As allied and German forces battled on the Continent, an eminent British scientist spoke openly of atomic war. In public lectures addressed to laypersons, he explained that while future energy shortages might be averted by using energy from the atom, the more probable result of the development of atomic power would be mass annihilation by weapons of inconceivable might. The distinguished speaker – handsome, articulate, and obviously worried – was not certain when this would occur.

The British government paid no attention to the seeming breach of national security, for no act of treason or even of indiscretion had been committed: The German troops were those of the Kaiser, and the year was 1915. The speaker, the 38-year-old Frederick Soddy, had recently completed research for which he would eventually be awarded the Nobel Prize in Chemistry.

Sclove then documents how Soddy, exceptional if not unique among his early-20th Century colleagues, divined the use to which the power of the atom – that is, the “possible technical uses” of special relativity – would be put and reorganized his intellectual life around his conclusions. Not only would Soddy’s understanding of such uses seem prescient, but his apparent foresight as well as his discovery with Ernest Rutherford that thorium decays (transmutes) into other elements was derived from a set of understandings about alchemy and other “so-called ‘nonscientific’ factors” (Sclove 1989: 163) in his life.

Interested from early in his career in the histories of chemistry and alchemy, Soddy (in Sclove’s telling) first understands the possibility of chemical transmutation – that is, the conversion of one chemical element into another – through understanding from J.J. Thompson’s discoveries that the atom is in fact divisible into smaller, charged particles (like electrons). Soddy then understands, through discoveries in the spectral analysis of star light, that transmutation in fact happens, albeit under extreme conditions. These new technical understandings cause him to reevaluate his history of alchemy, which he then locates not only prior to chemistry historically but intellectually as well. Then, “influenced by alchemy he proposed transmutation as chemistry’s ultimate goal weeks or months *before* discovering thorium transmutation” (Sclove 1989: 168; italics in the original). Soddy located his discovery of the transmutation of thorium in this alchemical narrative, from natural transmutation under extreme conditions in stars to natural transmutation under mundane conditions on earth, to the possibility of the alchemical

goal of intentional transmutation through “control of the internal forces of the atom” (Sclove 1989: 168).

As Soddy furthered his work with Rutherford, the two and others – particularly the Curies – began to clarify the nature of transmutation as radioactive decay and of the quantity of energy involved in this process, which they understood to be millions of times more powerful than known chemical reactions and explosives. Soddy suspected that transmutation and the release of the atom’s internal energy were intimately linked, and with Rutherford even imagined that such a process was crucial in the creation of energy from the sun and other stars. As if in an unstated counterpoint to Polanyi,⁴ Sclove (1989: 169) emphasizes that “these striking conclusions were based on theory and experimental evidence obtained prior to the development of the nuclear model of the atom and to Einstein’s formulation” of special relativity.

Soddy almost immediately became engaged in popular writing and speaking about the new discoveries and his vision for the uses to which this new knowledge would be put. Ultimately, he believed, the energy of the transmutation of the atom would provide “a source of mechanical and electrical power” that would drive bountiful, even utopian, transformations of the globe – even though he had, at the time, no idea of how the artificial and intentional transmutation of the atom that would release such energy would be accomplished or controlled. Nevertheless, Soddy relied on the track record of the scientific method and scientific ingenuity, as well as a very early understanding of the natural limits of fossil fuel-based growth (which had been an issue in Britain, related to the possible exhaustion of its coal mines, for decades).

Like many in Europe, Soddy’s optimism about the uses to which scientific knowledge might be put itself transmuted with the experience of The Great War. While technically challenged by the war-time research agenda imposed on him at the University of Aberdeen, he lamented the destructive uses to which his and others’ work was put. Continued personal transformations, including an increasing awareness of the day’s social issues and his staking out of progressive if not radical positions in them (e.g., for both women’s suffrage and Irish home rule), continued to influence his thinking about the potential applications of his science. A reading of H.G. Wells’ *The World Set Free* (1913), which was dedicated to Soddy and his work, coupled with the application of nitrogen-fixing technologies that had previously been used to create fertilizers to the development of explosives, helped generate a belief – contrary to Wells’ own view – that people would use any technical resource to secure military superiority. As early as 1915, Soddy speculated in public about the possibility of weapons derived from the energy within the atom, their stupendous destructiveness, and the likelihood that such weapons would not in fact render war impossible.

So here we have two stories of foresight regarding roughly the same research base and technological development – not quite a natural experiment, but illuminating nevertheless. First, it leads to an easy conclusion about seeing into the future of scientific discoveries and their “technical uses”: Foresight is not and should not be about prediction. The point is not to play “gotcha!” with Polanyi about his inability to foresee the bomb, in the way that the contemporary press corps plays with such public figures as politicians. Even with all the computational tools available to researchers, prediction is a

⁴ Sclove (1989: 188n90) makes a connection and contrast to Polanyi’s work, but only to the role of nonscientific sustenance of scientific inquiry and not to the role of foresight and its relationship to scientific autonomy and responsibility.

messy and even misguided business, e.g., prediction may not occur on scales of time or geography that are useful to policy makers, or accurate prediction may in fact not be necessary for the social action required in response to the event to be predicted (Sarewitz, Pielke and Byerly 2000). Giving Polanyi his due, there is no straight-line extrapolation or easy-to-fit curves from the understanding that the speed of light is a constant that describes the relationship between mass and energy to the ability, willingness, and commitment to design, test, deploy and drop on a human population an atomic bomb.

Yet Soddy also deserves his due, but not because, as scientists like to say, “the truth will out.” Soddy was surely closer to the mark than Polanyi – a veritable bullseye from three decades out compared with Polanyi’s clear miss from the distance of just a few months. But it would be a violation of an important methodological perspective in social studies of science and technology to make such a judgment, first, because the truth that willed out might have been another way and the bomb might not have been built but for numerous particular reasons; and second, the point of the inquiry is revealing what the social bases for the truth and its acceptance as truth ended up being. Rather, Soddy deserves his due for taking a serious question seriously, for grappling with the matters of his day as they related to his scientific research and his personal experiences, for engaging the public through lectures and writing about these issues even as he was grappling with them, and for envisioning a variety of “technical uses” of this line of work when at “present we have no hint of how even to begin the quest” (Sclove 1989: 170).

The second inference from the contrasting stories of Polanyi and Soddy is a complication that might be called “Polanyi’s dilemma,” and some consequent insight about how to extricate ones’ self from it.⁵ Despite his poor execution of it, Polanyi seems to believe that, in discussions of the practical uses of scientific discoveries, he and others should be in the business of prediction – were it possible. In saying that, at the time of Einstein’s 1905 publication, “another dozen or more discoveries had yet to be made before relativity could be combined with them to yield the technical progress which opened the atomic age,” Polanyi suggests that the ability to discuss the future practical uses of a discovery must be grounded in the most concrete and complete technical understanding – almost as if the outcome must be a necessary conclusion of that technical understanding. Yet, science “can advance only by essentially unpredictable steps” and, thus, we cannot know until it is upon us because any step in the interval between a premature prediction and a *fait accompli* may turn in a new and unforeseen direction. “*Eventura praediceamus, sed praedictio est impossibilis.*” We must predict events, but prediction is impossible.⁶

Polanyi’s route out of his *praediceamus* dilemma is an abdication, not only of his responsibility but of Einstein’s and, by extension, all scientists between. While he and Russell might be modestly embarrassed for failing to predict something that other scientists were in the final throes of creating, Polanyi concludes that therefore “it is obvious that Einstein could not possibly take these future consequences into account when he started on the problem.”

⁵ The dilemma is conceptually similar to the Collingridge (1980) dilemma about when in the development of a knowledge-based technology one might be able to intervene productively: early, when deviations are possible but understanding is limited; or later, when understanding is more robust but opportunities for change more difficult.

⁶ Douglas (2003) argues that foresight is an important capacity for discerning the general moral responsibility of human beings to prevent negligence or recklessness.

What to Expect of the Scientist, or “Soddy, You Shoes too Big”

Soddy shows that it is not obvious at all, for he concluded from his research and his observations on society: “It is our duty, therefore, to spend our lives and brains thinking this thing out for ourselves. It must not be left for our successors to relearn all over again” (in Sclove 1989: 179).

Soddy then took this duty seriously. After The Great War he turned more and more attention to what he viewed as the political and economic sources of the world’s woes – the ones, he felt, that might be healed so that his dark divination of war and the use of atomic weapons would not come to pass. He redoubled his earlier speaking and writing efforts to public audiences, and he became active in increasingly radical politics (Brownhill and Merricks 2002). He did not continue his Nobel-quality scientific work and, while he had moments of high public profile, he died in 1956 in what Sclove characterizes as relative obscurity – just over a decade after the atomic bombings of Hiroshima and Nagasaki seared his fears into human consciousness, and well into the teetering brinksmanship of the bomb-stocked Cold War.

Tragically, having spent the remainder of his life and brain “thinking this thing out” for himself, Soddy failed on at least two counts: Not only was he unable to convince a broader public that atomic weapons were a foreseeable and dangerous consequence of the physics being pursued between the world wars; but he was also unable, at least by Polanyi’s account, to have even the technical aspect of his argument register in the minds of scientists like Polanyi.

In his denial of what Soddy learned and imagined, let us first assume that Polanyi is not engaged in a post-hoc defense of the detached behavior of the community of physical scientists. Such a defense would not be unreasonable, for those physicists were after all subject both to opprobrium for their role in the creating the bomb, and then – as Oppenheimer and others – to scorn, humiliation and even prosecution for attempting to control what they had let loose. But a defense, anchored as Polanyi’s is in ignorance of consequences, is too facile. Let us further assume that Polanyi and Russell were not, in fact, aware of actual military progress on an atomic bomb and thus caught in an “on air” choice to either expose a state secret of critical importance to the war effort or feign ignorance at some risk their reputations. If this were the case, Polanyi never seemed to have let on in his writing after World War II, and the kudos that he would have earned for subjugating his ego to the war effort would then be lost for continuing to appropriate returns on a secrecy that was no longer required.

But it does seem odd that Polanyi would never have heard of Soddy’s vision, for he had certainly run across Soddy scientifically and politically. Although senior to Polanyi by a decade and a half, Soddy was closer in age to him than was the older Russell. Soddy was awarded his Nobel Prize in chemistry in 1921, four years after Polanyi earned his PhD in physical chemistry from the University of Budapest in his native Hungary. Although Polanyi did not emigrate to England until 1933, he and Russell were, along with Soddy, fellows of the Royal Society. Indeed, the two were at least nominal co-authors of an address published in the *Proceedings of the Royal Society*, delivered in 1934 by Soddy’s former collaborator Lord Rutherford and discussing in detail isotopic hydrogen, including earlier contributions by Soddy to developing the initial concept of

isotope (for which Soddy won his Nobel in 1921) and latter contributions by Polanyi in experimenting with heavy hydrogen (Rutherford et al. 1934).⁷

One imagines that Polanyi – and here I am speculating – that Polanyi must have heard of Soddy's vision, but that he found it unworthy of mention. Polanyi may have thought Soddy was taking too many liberties with the science to be making a credible prediction of the practical uses of relativity. He might have thought that Soddy's visions were like Wells' fantasy of bi-planes raining atomic bombs on cities – science fiction rather than science fact – and so dismissed them even unto the time when their underpinnings had been rendered technically concrete and complete.⁸ Polanyi may even have agreed with the sentiment expressed in Soddy's Nobel biography that “[a]fter [1919] he did no further work in radioactivity *and allowed the later developments to pass him by*. His interest was *diverted* to economic, social and political theories which gained no general acceptance, and to unusual mathematical and mechanical problems” (italics added).⁹

Or perhaps Polanyi rejected Soddy's vision because of their political differences. At that time, Soddy was a member of a group of British scientists, including J.D. Bernal, who came to be known as the “scientific humanists” for their critique of the value and ideology of pure science, in which sociologist Bernard Barber (1990) locates one of the multiple points of origin for an analytic sociology of science. Barber also recounts Polanyi's 1940 founding of the Society for Freedom in Science in direct response to what he and many colleagues saw as the challenge to scientific autonomy that the scientific humanists offered.¹⁰ Given the connection that Polanyi himself makes between foresight and autonomy, it would be exceptionally damaging to his vision of a free science if Soddy, decades earlier, had been able to predict the atomic bomb.¹¹

So after the Great War, Soddy – having given up his science, turned to social science and radical politics, and perhaps having therefore lost credibility about precisely those things he was passionate about¹² – does not seem a reasonable model for scientific responsibility. In his lifetime, he gave up too much, and he achieved too little, to ask that other scientists walk even a short distance in his shoes.¹³

Rather, I want to offer Soddy's career prior to the Great War as more like the model of responsibility that one can reasonably expect of a scientist. And the characteristics of

⁷ If I read the record properly, there seems to be something of a scientific dispute at the heart of this: Soddy, who won his Nobel for his isotope work and not for his transmutation work with Rutherford, believed at least initially that isotopes could not be separated chemically. It seems that Polanyi contributed to work that suggested, correctly, otherwise.

⁸ While there are good reasons to consider science fiction an important contribution to technology assessment (e.g., Miller and Bennett 2009), that is not the important distinction here.

⁹ Soddy's Nobel biography may be accessed at http://nobelprize.org/nobel_prizes/chemistry/laureates/1921/soddy-bio.html.

¹⁰ Barber (1990: 5) says that out of the conflict between the scientific humanists and the Society for Freedom in Science “came a somewhat better sociological understanding of the possibilities of predicting and planning science, both its discoveries and its social consequences.” My purpose in contrasting Polanyi and Soddy individually, of course, is to highlight exactly this point. Brownhill and Merricks (2002) similarly contrast the perspectives of Soddy and Polanyi, but making no mention of the scientific humanists as a group, add the more Marxist Bernal to draw a three-point comparison.

¹¹ Polanyi (1951: 197) continued to focus on the bomb for examples of the connection between unpredictability and scientific freedom in *The Logic of Liberty*. In that work, he does not seem to mention Soddy at all (he goes without entry in the index). In the earlier *Science, Faith and Society* (1964 [1946]), Polanyi mentions Soddy but once, in a strictly technical context as co-discoverer with Rutherford of transmutation.

¹² This description, part derived and part imagined, is not unlike the experience of other scientists who have turned to popularization and activism, including perhaps most prominently the late Carl Sagan whose work, while loved by the media and consumed rabidly by the general public, was far from valorized by his community of cosmologists.

¹³ Much later, however, Soddy is venerated by environmentalists for not only his insistence that scientists take explicit responsibility for the consequences of their work but also for his work on the relationship between energy and economics, which presages thought in environmental economics and sustainability (Brownhill and Merricks 2002).

his scientific responsibility are the same ones that, above, I singled out as reasons for praise in contrast to, simply, his being right: He took a serious question seriously. He grappled with the matters of his day as they related to his scientific research. He engaged the public through lectures and writing about these issues even as he was grappling with them. And for envisioning a variety of “possible technical uses” of this line of work when he had no idea of how, technically, the work would play out. This last characteristic is the essential one that distinguishes him from Polanyi who, after all, did appear on popular radio shows, did grapple seriously with public issues, and did eventually himself turn to social science.

Given that manifesting these characteristics of scientific responsibility do not require one to throw one’s career to the wind, as Soddy did, I would argue that they are at least somewhat more realistic expectations to have of scientists. Moreover, they do not require a scientist to be substantively correct about those practical uses; they only require that the scientist be serious and broad-minded and engaged and imaginative.

Nevertheless, it is reasonable to ask if scientists today are capable of fulfilling such responsibilities. The practice of science is of course much more highly bureaucratized than it was in Soddy’s day.¹⁴ As a recent study of the moral sensibilities of nano-scientists (Berne 2006) has demonstrated, many scientists are inspired to pursue a career in research because of their desire, simply put, to do good in the world. And yet they find themselves mired in a set of responsibilities – including seeking funding for their work, publishing and patenting their work, maintaining their laboratories for their own career and the careers of others – that pre-empts this impulse. They are frustrated moral agents, unable to pursue what they can identify as good because of the organizational imperatives of the doing of science. Perhaps even a relaxed version of Soddy’s responsibility seems troublingly beyond the reach of contemporary scientists.

What to Expect of the Social Scientist, or Douglas’s Dilemma

In an essay that directly challenges the claims on autonomy made by Polanyi’s Freedom of Science movement, philosopher of science Heather Douglas (2003) argues that scientists must satisfy their general moral responsibilities to avoid recklessness and negligence in the performance of their research. That is, they have some responsibilities for even the unintended consequences of their work and they are, *pace* Polanyi, “burdened with the same moral responsibilities as the rest of us (Douglas 2003: 59). While scientists may, like parents in Douglas’s (2003: 60) example, deserve sympathy and even some slack because their role responsibilities may conflict with their general responsibilities, the former do not relieve them of the latter. In their role responsibilities, scientists differ somewhat from professionals such as lawyers who are embedded in a social structure that relieves them of some of their general moral responsibilities in exchange for those role responsibilities, e.g., in service of identifiable clients defense attorneys are not required to reveal prior criminal acts because they are embedded in a larger social structure that bears the responsibility of finding criminals. Douglas argues that there is no such relief for scientists, in part because there are no social structures capable of substituting for their ability to prevent themselves from behaving recklessly or negligently and, if there were, any such structures would be fatal to scientific autonomy. This is her dilemma (although for now it is too complicated to render in Latin).¹⁵

¹⁴ Contrast, for example, Weber’s (19xx [1918]) “Science as a Vocation” with Hackett’s (1990) follow-on.

¹⁵ One might also argue that scientists, unlike lawyers, physicians and clergy, lack identifiable clients to whom their role responsibility would be paramount. See my discussion (Guston 2000: chap. 2) of the distinction between a “social contract for scientists” and a

In the rest of this essay, I would like to explore one possible social structure. I doubt that it would ever be as robust, institutionally or normatively, as the structure that protects attorneys. But neither do I think it will be as intrusive to the autonomy of science as Douglas worries any such system would be. It also has the virtues of corresponding, roughly, to the characteristics identified above with Soddy's early activities, and it offers to scientists assistance in fulfilling these responsibilities. Through it, scientists might find some justifiable protection against accusations of recklessness or negligence, and might even garner some praise for openness and responsibility, all at a cost that they, their students, and perhaps even their funding agencies might be willing to pay.

The insight behind this structure has roots in the same period that I have been discussing – and in the version of the dispute about scientific autonomy between Soddy and the scientific humanists on one side, and Polanyi and the Freedom of Science movement on the other, as it played here in the United States. While much of science policy in the United States after World War II pays homage to Vannevar Bush's *Science: The Endless Frontier* (1960 [1945]), the lesser-known *Science and Public Policy*, written by the economist John Steelman (1947) as President Truman's more populist alternative, provides some guidance. Steelman's report extends the government role beyond merely sponsoring research to organizing a more responsive research; he also advocates a special role for social scientists in assisting natural scientists in their social responsibilities: "Competent social scientists should work hand-in-hand with natural scientists, so that problems may be solved as they arise, and so that many of them may not arise in the first instance."¹⁶

Largely in collaboration with my colleague and co-author Dan Sarewitz, I have explored what this kind of "hand-in-hand" collaboration between the social and natural sciences might look like. In our initial paper on "Real-time Technology Assessment" (RTTA; Guston and Sarewitz 2002), we articulate an alternative kind of technology assessment to the one that we characterize as "science proposes, society disposes," and that is derived from the same vision of scientific autonomy, and general abdication of responsibility, as the Freedom of Science movement advocated. In particular, we propose a schematic, four-track method for "enhancing linkages between innovation and societal action in ways that can add to the value and capability of each" (Guston and Sarewitz 2002: 94).¹⁷ These tracks are:

1) analogical case studies – which creates "knowledge about *who* has responded to transforming innovations in the past, the *types* of responses that they have used, and the avenues selected for pursuing those responses [that] can be applied to understand connections between emerging areas of rapidly advancing science and specific patterns of societal response that may emerge" (italics in the original; p. 101);

"social contract for science," which in many ways parallels the distinction between role responsibilities and general moral responsibilities.

¹⁶ In Guston and Sarewitz (2002), we elaborate that Steelman's preface unearthed this quote from a report of the National Research Council from the 1930s that I have yet to be able to locate. Through the magic of Google Scholar, I have located a paper in which Detlev Bronk (1975: 413), who had been president of the Rockefeller University, president of the National Academy of Sciences, and chairman of the National Science Board, recalls speaking these words himself before Congress during testimony on behalf of the Committee Supporting the Bush Report. But reading Solovey (2004: 407), who discusses in great detail the dispute over the social sciences at the founding moments of the National Science Foundation, I find it unusual that Bronk would have thus testified as a member of the more conservative Committee Supporting the Bush Report, which otherwise opposed the explicit inclusion of the social sciences in the proposed foundation's research programs.

¹⁷ We owe a great debt to many people for the formulation of RTTA, including some practicing nano-scientists.

2) research program mapping – which “monitors and assesses current R&D activities at regional, national, and international levels...[and potentially] from a single laboratory to an entire field of innovation” (p. 102);

3) communication and early warning – which focuses on media content analysis, social judgment research, and public opinion research to help analysts and scientists understand “how public attitudes are evolving in the context of both historical trends (as developed in the case study activity) and evolving scientific capabilities (as developed in [research program mapping]” (p. 103); and

4) technology assessment and choice – which functions to elaborate and assess possible societal impacts and outcomes of emerging technologies with an emphasis on developing scenario-based deliberative and participatory processes, and then which reflexively evaluates the role of the entirety of RTTA activities on the evolving research agenda.

Quoting Guston and Sarewitz (2002: 105-06) at length about their vision for what RTTA would do:

- (a) Working with laboratories identified in the [mapping] activity, real-time TA researchers construct initial scenario for the impacts of nanotechnology, S.
- (b) Facilitated interaction between lab researchers and the lay public results in elaboration of scenarios S' and S”.
- (c) Lab researchers discuss scenario S' and S” with colleagues, think about different research questions or strategies, make different research or application development choices, or construct different consumer linkages.
- (d) Lay participants engage in real learning about the research and its possible applications.
- (e) Lab researchers and lay participants describe these activities in interviews, by logging them in web-based survey or in diaries, etc.
- (f) Real-time TA project documents emergence of S' or S”, in contrast to S, as an outcome.

Thus, the role of social scientists here is to perform a suite of research activities, many requiring the active involvement of natural scientists (and engineers), in an effort to assist scientists and members of the lay public to construct a more socially robust vision for emerging technologies.¹⁸

There are three related propositions upon which all parties need to agree for this collaboration to succeed. First, as Soddy believed but contrary to Polanyi, they must agree that is worthwhile talking about outcomes that are still open and not compelled by what is completely and concretely known. Second, as both Soddy and Polanyi believed, they must agree that we cannot know for sure which scenario will emerge. Third, again as Soddy but contrary to Polanyi, they must agree that there are at least some actions that we take in the present that can help us achieve better rather than worse outcomes for science in its social context.

¹⁸ This role for social scientists is specific rather than universal. In no way do I mean that their principal or dominant role is in service to natural scientists. Rather, I mean – as for natural scientists – their responsibilities include those to society more generally and collaborating with scientists is an important aspect.

It is subtle and challenging to see how this last proposition can be true and not conflict with the second, but it concerns Polanyi's *praediceamus* dilemma and our disposition toward the scenarios. The scenarios must be seen merely as plausible visions of the future and not "if-then" predictions of the future. RTTA co-produces outcomes, on the one hand, by challenging scientists to explore more reflexively their choices and practices that they think are potentially related to future outcomes and to inform those choices and practices with a broader set of values than otherwise; and, on the other hand, by challenging other actors like lay citizens to begin the process of understanding and engaging with emerging technologies in spaces other than the marketplace and in roles other than as consumer. As Guston and Sarewitz argue from Brunner and Ascher (1992: 311), the goal of the scenarios, as the goal of the social sciences in working with the sciences, is "not prediction with precision, [but] freedom through insight."

What to Expect of Governance (Now), or the CNS Resolution

Guston and Sarewitz (2002) offer no similarly detailed vision of the material and organizational support for such an RTTA capacity. Indeed, we lament that at the time "no US R&D programs of which we are aware include an integrated technology assessment component of the type presented here. However, ten years ago there were no ELSI programs attached to federal science initiatives, and today they are well accepted" (Guston and Sarewitz 2002: 108).¹⁹ I have also argued (Guston 2004) that research, training, and outreach for this vision of responsible innovation needed to be institutionalized broadly at research universities.

In 2004, the chance to put these ideas to a test arose. As part of its responsibilities under the National Nanotechnology Initiative, and as outlined by Congress in the Twenty-first Century Nanotechnology R&D Act of 2003 (see Fisher and Mahajan 2006), the National Science Foundation issued a call for proposals for a Center for Nanotechnology in Society. While RTTA was central to the structure of the proposal that Sarewitz and I put together, we had modified it slightly to make it more operational within the human and financial resources we could expect. We also tentatively introduced the concept of anticipatory governance as a more strategic-level consideration to unify the methodological approach of RTTA.

Anticipatory governance was a phrase we had used almost in passing in the RTTA paper, and since then Karinen and Guston (2009) have done additional research on its genealogy. We find that the term does not seem to appear in the literature, save in one Canadian master's thesis (Feltmate 1993), prior to 2001. By that time, it appears severally and in somewhat different forms in the fields of public administration (e.g., Baechler 2001) and of environmental studies (Gupta 2001). Guston and Sarewitz (2002) introduce it to the nano-in-society literature, and these literatures remain largely separate – not citing each other's uses of the term. So a number of scholars were playing with the term at roughly the same time.

A particularly compelling antecedent to these discussions comes from the futurist-sociologist Alvin Toffler (1970), who introduced and developed the term "anticipatory democracy" in his best-selling *Future Shock*. Many direct descendants of this usage

¹⁹ ELSI is the "ethical, legal and social implications" program that was created as part of the Human Genome Initiative. See Cook-Deegan (1994).

(e.g., Chi 2008), focus almost exclusively on the use of foresight methodologies – most often forecasting and modeling – as the source and style of anticipation. And contrary to Toffler’s own emphasis on the failure of technocratic modes and the need for distributed, popular engagement (with echoes in our anticipatory governance below), this literature shows the heavy influence of more traditional ideas about strategic and long-range planning. This focus is not surprising, as the primary audience for this literature has consolidated around state governments, whose policy agendas are dominated by budget forecasting and demographic change. Nevertheless, this approach holds, as Polanyi: *eventura praediceamus*.

Sed praedictio ist impossibilis.

Through late 2004 and early 2005, Sarewitz and Guston worked on a proposal to NSF for a Center for Nanotechnology in Society at Arizona State University (CNS-ASU), developing ideas about anticipatory governance in a more-or-less ad hoc fashion, although by the time NSF awarded a CNS-ASU in October 2005, the Center had settled on a definition that focused on a broad societal capacity that was enhanced through early connections to the research process and diminished when R&D decisions were reified in market products (Sarewitz and Guston 2005). Soon thereafter, as the demands of implementing CNS-ASU led to a greater need for articulating a meaningfully concrete strategic vision, my colleagues and I began to flesh out more formally what anticipatory governance would mean to us: an overarching, strategic vision that helps guide RTTA by providing for three directions for research – foresight, engagement and integration – as well as for their “ensemble-ization” or their inter-relation (Barben et al. 2008; Guston 2008).

Foresight, the first component of anticipatory governance, is meant to be an area of research that acknowledges the imperative to deal with future events, but in a way that does not rely on trying to predict them. CNS-ASU’s approach has applied scenario development methods to explore multiple, plausible futures and then render those scenarios for use in various deliberative and pedagogic contexts. In one traditional scenario development workshop (Selin 2008), researchers, legal experts, health care providers, and CNS personnel imagined plausible futures for a personalized medicine technology dubbed “doc-in-the-box,” in which a laptop-sized machine would reside in people’s homes, and they would regularly deposit a very small amount of bodily fluid for the doc-in-the-box to analyze for hundreds or thousands of biomarkers for pre-symptomatic disease diagnosis. Not only did the scenario development workshop elaborate the kinds of data ownership, privacy, and power issues involved in the networks that would be necessary to make doc-in-the-box work as intended, but it also influenced how the researchers approached the problem (akin to the transformation of scenario S into S’): first, a senior researcher had not, until the scenario workshop, fully appreciated the problem of technological lock-in, which might mean that the first-to-market application of doc-in-the-box could substantially condition applications to follow, causing him to reconceive the particulars of that first-to-market application; and second, a graduate student realized that she did not want to do research on a bio-marker for a disease for which there was currently no cure, causing her to change her research topic. In a less traditional approach (Bennett 2008), we generated brief scenarios or “scenes,” imaginative and yet grounded in technical and popular literatures. After being vetted by experts, these scenes were then incorporated into various activities for dissemination

and use, including: our NanoFutures web site,²⁰ courses such as InnovationSpace, which require cross-functional teams of engineering, design, and business students to produce plans and prototypes for new nano products (Selin et al. under review); the background document for the National Citizens' Technology Forum (see below), which prepared 75 citizens to participate in nation-wide deliberative exercise on nanotechnologies and human enhancement;²¹ and other uses. Still other CNS-ASU research uses the inspiration of anticipatory governance to assess others' claims about the future of nanotechnologies, e.g., by making an empirical inquiry of such questions as whether nanotechnology will be a general purpose technology (Youtie et al. 2008) and whether "active nanostructures" are emerging as per a noted roadmap of nano development (Subramanian et al. 2009).

Engagement, the second component of anticipatory governance, is meant to be an area of research that acknowledges the need to involve members of the lay-public, early and diversely, in discussing the goals of the nano research enterprise and the values of the public and scientists alike. CNS-ASU uses a number of different techniques of elicitation and engagement, and we have found them to be complementary in important ways, e.g., findings from a large-scale, national public opinion survey on attitudes toward and knowledge of nanotechnologies (e.g., Broussard et al. forthcoming) provide a high-level, statistically satisfying view of the role of religiosity in the formation of attitudes toward nanotechnologies; while intimate focus groups (e.g., Milford 2008) provide a more sensitive and nuanced portrayal of individuals' perspectives and expressions of those attitudes. One can, of course, argue that opinion polling is not "engagement," even if it serves complementary goals. Thus a centerpiece to the engagement activities of CNS-ASU has been its National Citizens' Technology Forum (NCTF), held in Spring 2008 on nanotechnologies and human enhancement.²² In the NCTF, 75 lay-citizens participated in a Danish-style consensus conference (see Guston 1999), held in six locations across the country. The process was very intensive (see Hamlett et al. 2008). CNS researchers advertised for participants in multiple media, screened them for conflicts of interest, and matched them demographically to the local population for selection. Once selected, participants took an extensive pre-test and received a 61-page background document prior to meeting face-to-face in each locale for two full days of conferring. They then conferred across locales through the Internet for 9 two-hour sessions,²³ including interactions with five substantive experts before reconvening in their local groups for face-to-face deliberations and drafting of their site-specific reports.²⁴ After completing their reports and, in total, some 32 hours of face-to-face work, 18 hours of Internet work, and additional time on their own, the participants completed the post-test and received \$500 for their efforts. Substantively, the NCTF demonstrated significant harmony across sites on important issues like public information, oversight, and equity issues, as well as some interesting variations (Hamlett et al. 2008). It also showed that the participants learned a significant amount about the topic, distinguished among various plausible applications, and valued therapies much more highly than enhancements, of which they ultimately disapproved. Data from the pre- and post-tests also suggested that the interactions among the lay-citizens were not plagued with the kinds of pathologies that are often attributed to small-group deliberations, e.g., there was

²⁰ See <http://cns.asu.edu/nanofutures>.

²¹ Available at <http://www4.ncsu.edu/~pwhmds/BackgroundMaterials.pdf>.

²² Still more informally, CNS-ASU offers a Science Café every month during the academic year in conjunction with the Arizona Science Center.

²³ Delborne et al. (forthcoming) assess the virtual interactions of the NCTF and find them somewhat lacking, but mostly in ways that might be fixed through different choices in software and techniques of moderating.

²⁴ Each site report is available at http://www4.ncsu.edu/~pwhmds/final_reports.html.

no “polarization cascade” in which an initial majority group induced others to join their majority position for reasons other than reasoned argument. While the NCTF was designed as a research-and-demonstration project, as no national deliberative forum of this kind had been conducted in the US (with so many participants, across three time zones, etc.), the reports produced by the citizens in fact provided information of sufficient quality and relevance to warrant communication with Congress about it (Philbrick and Barandiaran 2009).²⁵

Integration, the third component of anticipatory governance, is meant to be an area of research that acknowledges Steelman’s insight, that social scientists have an opportunity – and, likely, a role responsibility – to collaborate with natural scientists and engineers in mutual efforts to improve the eventual outcomes of research and innovation. While there are integrative elements in each of the programs discussed above – the vetting of scenes by nano researchers and their participation, along with social scientists, humanists, and practitioners in scenario development workshops, or the participation of nano researchers as experts in communication with NCTF participants – the focus of CNS-ASU’s integrative activity has been working directly with scientists and engineers in the laboratory, and with science and engineering students in research, curricular and co-curricular activities. In one type of laboratory engagement, two CNS-ASU researchers met with nano-researchers during their regular lab group meetings. Over the course of one semester, these meetings resulted in greater understandings on the part of both students and faculty in the lab of the societal aspects of their work and, perhaps more provocatively, seeded discussions about societal aspects of the research among the lab members when the CNS-ASU researchers were nowhere to be found (McGregor and Wetmore 2009). This project spurred a more extensive attempt, funded by the National Science Foundation’s Ethics Education in Science and Engineering program, to evaluate and compare different modes of ethics instruction from online modules, classroom curricula, and laboratory meetings.²⁶ In another type of laboratory engagement, a doctoral student was “embedded” in a nano-materials laboratory for 33 months and, in collaboration with the lab director, developed a protocol to probe whether his mere presence in the laboratory asking questions might modulate research toward more productive outcomes (Fisher, Mahajan and Mitcham 2006). Success with this project led the “embedded humanist,” Erik Fisher, to modify his protocol modestly so that it could be replicated by other embedded researchers in other laboratories who, by conducting studies of laboratories in different countries, could also gain comparative leverage on laboratory cultures and their capacities to respond to different policy environments. This Socio-Technical Integration Research, or STIR,²⁷ project has been funded by the National Science Foundation and is beginning to yield results as promising as the model investigation (Schuubiers and Fisher 2009). Research activities with doctoral students in nano-science include what we call the PhD+ program, which requires the student to take on a social science or humanist mentor and perform a significant research project in the societal aspects of his or her own nano research. In one completed PhD+, Lappe (2009) explores the changing landscape of patent law, and its potential influence on academic research, since the Supreme Court’s 2007 *Teleflex* decision that rendered the research leading to his doctoral degree unable to be patented. Curricular and co-curricular activities include a series of one-credit

²⁵ In private communication, Philbrick offers some plausible evidence that contact with congressional staff about the NCTF has influenced language in the current Senate bill to reauthorize the National Nanotechnology Initiative.

²⁶ For a summary of Integrating Microethics and Macroethics in Graduate Science and Engineering Education, see <http://cns.asu.edu/program/eese.htm>.

²⁷ For a summary of STIR, see <http://cns.asu.edu/stir/>.

courses for science and engineering doctoral students and two-week immersion seminars in Washington, DC and abroad that “dis-orient” students to the world of science outside their laboratories. All of these integrative activities rely on the openness of natural scientists and engineers to collaboration with social scientists and even the former committing some of their precious grant money to such activities.²⁸

Conclusion, or Keep the Heavens Up

In 1935, Frederick Soddy wrote the foreword to a collection of essays, *The Frustration of Science*, representing the thought of the scientific humanists. He believed the book to be “indicative of the growing sense of social responsibility, among some individuals of scientific merit at least, for the world the labours [sic] of their order have so largely created” (Soddy 1975 [1935]: 7). He further alleged that:

The public expect far more from scientific men in this respect than they have as yet contributed. Individually most of them in this field are still utterly unscientific, and quite as apt as the public themselves to regard individual thought on these subjects as socially dangerous and to be suppressed and those who have strayed from the path of “pure” science in these directions as cranks or imposters....

On the other hand, the public must not expect too much. They are apt to forget that in effect, as an entity with power of acting, they hardly exist, until *in extremis* when it is too late. The pioneer and bearer of a new evangel is always up against an inchoate mass, educable only when miserable and, when prosperous, too proud to learn. This much at least of justification can be offered for the doctrine, so utterly the opposite of the truth for the individual, that suffering is the great goad to progress. Unfortunately, scientific powers of inflicting mass suffering are now so powerful that once started they are hardly likely to stop so long as there is anyone left to suffer....

The solution is for the public to...require that its universities and learned societies should no longer evade their responsibilities and hide under the guise of false humility as the hired servants of the world their work has made possible, but do that for which they are supported in cultured release from routine occupations, and speak the truth though the heavens fall (Soddy 1975 [1935]: 7-9).

Again, Soddy exceeds my purpose, but offers vital insight. Anticipatory governance is an attempt to *mediate* between the conflicted scientists and public in this account, *moderate* both's belief that such discussions are “socially dangerous,” *modulate* the scientists' behavior toward the more generally responsible, and *remediate* the public's tendency to wait until tragedy strikes before it is willing to learn. The activities in foresight, engagement, and integration that we have piloted at the Center for Nanotechnology in Society at Arizona State University are still but modest offerings in these directions. While implementing them requires the kind of cultural and institutional change at universities that Soddy calls for – indeed, even friendly critics have alleged

²⁸ E.g., Assistant professor Jonathan Posner from ASU's Ira Fulton School of Engineering recently received an award from the National Science Foundation that commits funds to support these kind of curricular and co-curricular activities for his students.

that our activities might be limited to the fertile climate for social experimentation that President Michael Crow has induced at ASU – expanding these innovations across the research enterprise does not require bringing the heavens down.

Postscript, or The Pumpkin or the Tiger?

In a later essay, also published in *Minerva*, Polanyi (1967) seems to back off of his *praediceamus* demand. In “The Growth of Science in Society,” he introduces the concept of “plausibility” to a discussion of the mediation of disputes within science and between science and what one might call pseudo-science. To Polanyi, the operation of plausibility explains why scientists may disregard some hypotheses: “Only plausible ideas are taken up, discussed and tested by scientists. Such a decision may later be proved right, but at the time that it is made, the assessment of plausibility is based on a broad exercise of intuition guided by many subtle indications, and *thus it is altogether undemonstrable. It is tacit*” (Polanyi 1967: 536; italics in the original). Such tacit reasoning allows scientists to dismiss with prejudice, in his example, Immanuel Velikovsky’s ideas that a rogue comet first caused a number of events described in the Hebrew bible and then settled into orbit to become the planet Venus – despite the fact that spacecraft later confirmed Velikovsky’s hypothesis, contrary to the expectation of many planetary scientists, that Venus was hot and had plentiful hydrocarbons in its atmosphere.

In other examples, Polanyi describes how plausibility operates in science even for more pedestrian claims, and operates as well to exclude ideas that ultimately prove correct as well as ideas that never enter the canon. In attempting lay out some analytic version of this intuition, he dismisses reliance on the pragmatic, technological success of science (because Lysenko-ism in the Soviet Union persisted for so long despite its practical failures in agriculture). Rather, Polanyi (1967: 542) offers a suite of characteristics that make a hypothesis or finding “interesting to science.” One is reliability, or exactitude. The second is its systematic importance to the rest of scientific knowledge. The third is the intrinsic interest of the subject matter.

Using these characteristics as a yardstick to measure Soddy’s vision of the atomic energy and the atomic, I cannot imagine low scores on the measures of systematic importance or intrinsic interest (although of course “cannot imagine” is not a good criterion!). That leaves exactitude or reliability. One could be tempted to evaluate exactitude or reliability by asking if all the pieces are in place. (Polanyi himself might have used such a phrase, as in “The Republic of Science” as well as in “The Growth of Science in Society” he uses puzzle metaphors to express the scientific task.) Indeed, this is how Douglas – in a new book extending her earlier paper – seems to evaluate the visions of atomic energy. Once Hahn, Frisch and Meitner had identified the fission of uranium, one would say, all the pieces fell into place: “As word of fission crossed the Atlantic in January 1939, it was clear to all what fission meant: the possibility for useful nuclear energy, either as a power source or a bomb” (Douglas 2009: 83). Yet this word had not yet reached Polanyi, if we take him at his word, by January 1945, and even Einstein (as Douglas rightly points) needed Szilard to rouse him to this possibility. And perhaps, even at the risk of exculpating Polanyi, all the pieces were not in place, as many years of many scientists’ and engineers’ labors lay stretched out six or seven years into the future ushered in at Trinity.

But “having all the pieces in place” or even all of them face up, seems too great a demand to place on mere plausibility: likelihood, eventuality, or even in Douglas’s words “possibility” could bear this. But plausibility is a weaker, more exploratory concept than any of these. Pushing Polanyi’s puzzle metaphor, I would argue that plausibility is more about having enough of the pieces turned up that you can begin to conceive of what the complete picture might look like. Enough orange and black pieces would have you thinking tiger or jack-o-lantern. If the puzzle pieces are really bits of reality, is it not at this point that you would want to start asking, “what happens if it is a tiger?”

References

- Baechler, G. 2001. "Conflict Transformation through State Reform." In *Berghof Handbook for Conflict Transformation*. http://www.berghof-handbook.net/uploads/download/baechler_handbook.pdf. Last accessed 2 September 2009.
- Barben, Daniel, Erik Fisher, Cynthia Selin, and David H. Guston. 2008. "Anticipatory Governance of Nanotechnology: Foresight, Engagement, and Integration." Pp. 979-1000 in E. J. Hackett, O. Amsterdamska, M. E. Lynch, and J. Wajcman, eds., *The New Handbook of Science and Technology Studies*. Cambridge: MIT Press.
- Barber, Bernard. 1990. *Social Studies of Science*. New Brunswick, NJ: Transaction Publishers.
- Bennett, Ira. 2008. "Developing Plausible Nano-Enabled Products." Pp. 149-55 in *Yearbook of Nanotechnology in Society, Vol. 1: Presenting Futures*, Jameson Wetmore, Cynthia Selin, and Erik Fisher, eds. David H. Guston, series editor. New York: Springer.
- Berne, Rosalyn. 2006. *Nanotalk: Conversations with Scientists and Engineers about Ethics, Meaning, and Belief in the Development of Nanotechnology*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Bronk, Detlev W. 1975. "The National Science Foundation: Origins, Hopes, and Aspirations." *Science* 188(4187):409-14.
- Brossard, Dominique, Dietram A. Scheufele, Eun-Sung Kim, and Bruce V. Lewenstein. Forthcoming. "Religiosity as a Perceptual Filter: Examining Processes of Opinion Formation about Nanotechnology." *Public Understanding of Science*.
- Brownhill, R. and L. Merricks. 2002. "Ethics and Science: Educating the Public." *Science and Engineering Ethics* 8:43-57.
- Brunner, Ronald D. and William Ascher. 1992. "Science and Social Responsibility." *Policy Sciences* 25:295-331.
- Bush, Vannevar. 1960 [1945]. *Science: The Endless Frontier*. Washington, DC: National Science Foundation.
- Chi, Keon S. 2008. *Four Strategies to Transform State Government*. Organizational Transformation Series. Washington, DC: IBM Center for the Business of Government.
- Collingridge, David. 1980. *The Social Control of Technology*. New York: St. Martin's Press.
- Cook-Deegan, Robert M. 1994. *The Gene Wars: Science, Politics and Human Genome*. New York: WW Norton & Company.
- Delborne, Jason A., Ashley A. Anderson, Daniel Lee Kleinman, Mathilde Colin and Maria Powell. Forthcoming. "Virtual Deliberation: Prospects and Challenges for Integrating the Internet in Consensus Conferences." *Public Understanding of Science*.

- Douglas, Heather E. 2009. *Science, Policy and the Value-Free Ideal*. Pittsburgh: University of Pittsburgh Press.
- _____. 2003. "The Moral Responsibilities of Scientists (Tensions between Autonomy and Responsibility)." *American Philosophical Quarterly* 40(1):59-68.
- Fisher, Erik and Roop L. Mahajan. 2006. ["Nanotechnology Legislation: Contradictory Intent? U.S. Federal Legislation on Integrating Societal Concerns into Nanotechnology Research and Development."](#) *Science and Public Policy*, 33(1): 5-16.
- Fisher, Erik, Roop L. Mahajan and Carl Mitcham. 2006. ["Midstream Modulation of Technology: Governance from Within."](#) *Bulletin of Science, Technology and Society*, 26(6): 486-496.
- Gupta, Aarti. 2001. *Searching for Shared Norms: Global Anticipatory Governance of Biotechnology*. Doctoral Dissertation, Yale University.
- Guston, David H. 2008. "Innovation Policy: Not Just a Jumbo Shrimp." *Nature* 454:940-41.
- Guston, David H. 2004. "CRIs in the Wilderness: Toward Centers for Responsible Innovation in the Commercialized Academy." Pp. 161-74 in D. Stein, ed. *Buying in or Selling Out: Essays in the Commercialization of the American Research University*. New Brunswick: Rutgers University Press.
- _____. 2000. *Between Politics and Science: Assuring the Integrity and Productivity of Research*. New York: Cambridge University Press.
- _____. 1999. "Evaluating the First U.S. Consensus Conference: The Impact of the 'Citizens' Panel on Telecommunications and the Future of Democracy.'" *Science, Technology & Human Values* 24(4):451-82.
- Guston, David H. and Daniel Sarewitz. 2002. "Real-time Technology Assessment." *Technology in Society* 24(1):93-109.
- Hackett, Edward J. 1990. "Science as a Vocation in the 1990s: The Changing Organizational Culture of Academic Science." *The Journal of Higher Education* 61(3):241-79.
- Hamlett, Patrick, Michael D. Cobb, and David H. Guston. 2008. *National Citizens' Technology Forum: Nanotechnologies and Human Enhancement*. CNS-ASU Report #R08-0002. Tempe, AZ: Center for Nanotechnology in Society at Arizona State University.
- Latour, Bruno and Steve Woolgar. 1979. *Laboratory Life: The Social Construction of Scientific Facts*. With an introduction by Jonas Salk. Beverly Hills, CA: Sage.
- McGregor, Joan and Jameson Wetmore. 2009. ["Researching and Teaching the Ethics of Social Implications of Emerging Technologies in the Laboratory."](#) *Nanoethics*, 3(1): 17-30.

- Merton, Robert. 1938. "Science, Technology and Society in Seventeenth Century England." *Osiris* 4:360-632.
- Milford, Richard. 2008. *A Dialog on Nanotechnology and Religion: New Methods in Public Engagement*. Undergraduate Honors Thesis. Barrett Honors College, Arizona State University. Tempe, AZ.
- Miller, Clark A. and Ira Bennett. 2009. "Thinking Longer Term about Technology: Is There Value in Science Fiction-Inspired Approaches to Constructing Futures?" *Science and Public Policy* 35(8):597-606.
- Philbrick, Mark and Javiera Barandiaran. 2009. "The National Citizens' Technology Forum: Lessons for the Future." *Science and Public Policy* 36(5):335-47.
- Polanyi, Michael. 1967. "The Growth of Science in Society." *Minerva* 5(4):533-45.
- _____. 1968 (1962). "The Republic of Science: Its Political and Economic Theory." *Minerva* 1(1):54-73; reprinted in Shils.
- _____. 1951. *The Logic of Liberty: Reflections and Rejoinders*. London: Routledge and Kegan Paul, Ltd.
- _____. 1964 [1946]. *Science, Faith and Society: A Searching Examination of the Meaning and Nature of Scientific Inquiry*. Chicago: The University of Chicago Press.
- Rutherford, [E], N.V. Sidgwick, F.W. Aston, P. Harteck, F. Soddy, M. Polanyi, E.K. Rideal, R.H. Fowler, R.P. Bell, J.D. Bernal, and W. Jevons. 1934. "Discussion on Heavy Hydrogen: Opening Address." *Proceedings of the Royal Society of London, Series A* 144(851):1-28. Available at www.jstor.org/stable/2935574.
- Sarewitz, Daniel and David H. Guston. 2005, July. "New Frontiers of Technology Assessment." Presented at Nanotechnology: Science, Economy, Society. Marburg, Germany.
- Sarewitz, Daniel, Roger A. Pielke, Jr. and Radford Byerly, Jr. 2000. *Prediction: Science, Decision Making, and the Future of Nature*. Washington, DC: Island Press.
- Schuurbiens, Daan and Erik Fisher. 2009. "[Lab-scale Intervention](#)." *EMBO Reports*, 10(5): 424-427.
- Sclove, Richard E. 1989. "From Alchemy to Atomic War: Frederick Soddy's 'Technology Assessment' of Atomic Energy, 1900-1915." *Science, Technology & Human Values* 14(2):163-94.
- Selin, Cynthia. 2008. *The Future of Medical Diagnostics*. Tempe, AZ: Center for Nanotechnology in Society at Arizona State University.
- Selin, Cynthia, Prasad Boradkar and Adelheid Fischer. Under review. "Prototyping Nanotechnology: A Pedagogic Approach to Responsible Innovation." *Journal of Nanotechnology Education*.

Shils, Edward, ed. 1968. *Criteria for Scientific Development: Public Policy and National Goals*. Cambridge: MIT Press.

Soddy, Frederick. 1975 [1935]. "Foreword." Pp. 7-9 in *The Frustration of Science*, edited by David Hall. Reprinted by Arno Press, Inc.

Solovey, Mark. 2004. "Riding Natural Scientists' Coattails onto the Endless Frontier: The SSRC and the Quest for Scientific Legitimacy." *Journal of the History of the Behavioral Sciences* 40(4):393-422.

Steelman, John R. 1947. *Science and Public Policy*. (5 Vols.). The President's Scientific Research Board. Washington, DC: US Government Printing Office.

Subramanian, Vrishali, Jan Youtie, Alan L. Porter, and Philip Shapira. 2009. "Is There a Shift to 'Active Nanostructures'?" *Journal of Nanoparticle Research* (published online on 25 August 2009; DOI 10.1007/s11051-009-9729-4).

Toffler, Alvin. 1970. *Future Shock*. New York: Random House.

Weber, Max. 1991. [1918]. "Science as a Vocation." Pp. 129-56 in *From Max Weber: Essays in Sociology*. Edited by Hans Gerth and C. Wright Mills. New York: Routledge.

_____. 2002 [1905]. *The Protestant Ethic and the Spirit of Capitalism*. Edited and Translated by Peter Baehr and Gordon C. Wells. New York: Penguin Books.

Youtie, Jan, Maurizio Iacopetta and Stuart Graham. 2008. "[Assessing the Nature of Nanotechnology: Can We Uncover an Emerging General Purpose Technology.](#)" *Journal of Technology Transfer* 33: 315-329.

Gendered Risk Beliefs about Emerging Nanotechnologies in the US

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US “publics” are asked to play a significant role in the National Nanotechnology Initiative (NNI), a multi-billion dollar investment plan to “revolutionize” new technology R&D. One nearly invisible issue in this proposed process for democratic citizen participation is how the politics of difference in the US affects engagement. Based on findings from workshops held with carefully selected stratified samples, we ask how participants in the US from different social locations (by gender and race/ethnicity as well as age, education, and occupation) respond distinctly to deliberative workshops concerning science and emerging (nano)technologies for health and energy. Past studies have shown that gender and race/ethnicity produce significant differences in risk perception in response to many other technologies. For instance, the “white male effect” documents the ubiquitous finding that young white males, particularly those who are better educated, are more accepting of science and technology in general - and of virtually all technologies specifically - than are women or persons of color. Yet surprisingly little attention has focused on this profound gendered and raced difference, or its implications for the national project of citizen inclusion, collaboration, and engagement. This study examines the ways that social difference inflects social acceptance of technologies, and discourses of benefit and risk among engaged publics in response to new nanotechnologies. The study is part of the research program of the Center for Nanotechnology in Society at UCSB.

Introduction^{1, 2}

Although we can debate whether nanotechnologies today represent ‘upstream’ or ‘midstream’ development, in terms of public perceptions, nanotechnologies remain very much upstream. A meta-analysis of published surveys from around the world shows that public awareness or familiarity continues to be very low (Satterfield, Kandlikar, Beaudrie, Conti & Harthorn 2009). This paper discusses research that asks how and through what processes technologies that barely exist in the public’s awareness emerge already profoundly gendered, raced, and otherwise socially marked? And then we ask: what are the implications of this for the national project in the US of citizen inclusion, collaboration, and engagement associated with the National Nanotechnology Initiative

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(NNI) in general and our National Science Foundation-funded national center in particular?

The research we discuss is part of a collaborative research effort by an interdisciplinary, international research team led by the first author in the NSF-supported Center for Nanotechnology in Society at UC Santa Barbara. The team is highly interdisciplinary and includes 3 anthropologists, 3 sociologists, 2 social psychologists, 2 geographers, 2 environmental policy people, 2 nanoscientists (a chemist and an electrical engineer), and among the other hats she wears, the first author is a professor of feminist studies. The team is also international—the 3 leaders (Harthorn, Pidgeon and Satterfield) are based respectively in the US, UK and Canada. In specific for the deliberation research reported here, the main other contributors include the co-authors, sociologists Karl Bryant and Jennifer Rogers, social psychologist Nick Pidgeon, cultural geographer Tee Rogers-Hayden, as well as anthropologist Terre Satterfield, geography student Indy Hurt, and chemistry student Tyrone Martin.

In this paper we address the question we are often asked: “what in the world does gender have to do with nanotechnologies?” To do that we first discuss how “social location” is theorized to have an effect on perceptions, including those to do with new technologies and their introduction into society. We then describe qualitative research we’re engaged in to look at the ways views emerge and are articulated in a deliberative setting. This includes discussion of gendered aspects of a study completed in 2007 and reported earlier this year in *Nature Nanotechnology* (Pidgeon, Harthorn, Bryant & Rogers-Hayden 2009), as well as a new study currently in progress (Harthorn 2009, with Rogers & Bryant). And finally, we close with some implications of these studies.

Nanoethics, itself an emergent field of inquiry, we argue should include attention to issues of social justice and equitability in mandated public participation, as well as systematic reflection on the wider and deeper implications of technological change and the diversity of views on its benefits and constraints on realization of benefits. Equitable development is a fundamental aspect of the promises accompanying public funding of nanotech R&D (in the US). Gendered differences in social distribution of technological benefit and harm as well as the perception of such differences could threaten the nanoenterprise.

Background

Gendered perceptions

First, we provide some brief background about our approach to nanotechnologies and public attitudes about their benefits and risks, to make clear the parameters for the gendered differences we discuss below. Our focus on risk perception is based on thirty years of behavioral research that have contributed a well developed understanding of the ways perceptions drive behavior (Krimsky & Golding 1992; Lichtenstein & Slovic 2006; Pidgeon et al. 1992; Pidgeon, Kasperson and Slovic 2003; Slovic 2000). Hence, we argue that risk perception is one likely strong indicator of anticipated response to nanotechnologies. “Risk perception” in this approach includes not just perceptions per se, but also what we as cultural anthropologist and sociologists would call cultural beliefs and values. This research also demonstrates the view amply represented in science and technology studies and the social sciences, but not so evident in many science and engineering contexts in the US—that public risk perceptions or beliefs are not just ignorance or misunderstanding, and that expert risk assessment (such as

nanotoxicology) will not necessarily change those views (Freudenburg 1988; Irwin and Wynne 1966; Slovic 2000; Wynne, Wilsdon and Stilgoe 2005). Based on those understandings, we argue that nanotech risk perception will be driven primarily by a combination of factors that include: a) perceiver attributes; b) nanotech object attributes; and c) the process through which risk communication takes place. We also consider the ways in which the nanotech case might be unique, and indeed we are arguing in other research (e.g., Satterfield, Kandlikar, Beaudrie, Conti and Harthorn 2009) that there are both classic and new features emerging, from a risk perception standpoint. In particular in our survey research we are trying to understand benefit perception by looking closely at the experimental conditions under which reversals of opinion about risks and benefits emerge (Satterfield, Conti, Pidgeon and Harthorn, 2009, in preparation).

Nanotechnologies as risk objects hold particular fascination for risk perception researchers because they seem at first analysis to have many of the characteristics of technological risk objects that previous research has shown to lead to amplified risk perception and lowered acceptability (Pidgeon, Kasperson and Slovic 2003; Slovic 2000). The most relevant of these characteristics include:

- the novelty of the object (see Rayner 2004; and our research indicates novelty is viewed very differently by scientists and some members of the public)
- its invisibility (which is a definitional characteristic of anything at the nanoscale—and therefore visualizing, imaging or monitoring it requires more specialists and more technology; see Erikson 1994; Freudenburg 1996)
- exposure to the object is involuntary (e.g., such as that arguably occurring with many personal care nano products currently in the marketplace)
- distribution of the risks and benefits is potentially inequitable (our research has found that nanotech medical technologies strongly symbolize this characteristic to both US and UK publics)
- ‘man-made’ vs. ‘natural’ composition (which synthesized nanomaterials are by definition, and publics in our research definitely focus on this as an issue)
- the technology is poorly understood by science (one of nanotechnologies’ hallmark characteristics, although some scientists dispute this characterization)
- and apparent violation of ‘dose makes the poison’ logic whereby smaller bulk quantities should be less toxic.

You can see that nanotechnologies have a very high number of risk factors for being viewed as risky by lay persons. But what are the essential differences among different sectors of the public in the ways they actually view nanotechnologies as agents of potential harm? And what kinds of benefits figure in those diverse publics’ imaginings of nanotechnological futures? Those are the driving questions in CNS-UCSB risk perception research.

The national project of nanotech R&D in the US, which included a 1.5 billion dollar federal investment in 2008, embraces a technocratic vision of harnessing these new technologies for social benefit (NNI 2009a, 2009b). Public participation in technological development has been a recognized political necessity in the US at least since the mid-1990s, with the endorsement of the analytic deliberative model (Stern and Fineberg 1996; Renn 1999). Yet there has been a striking absence of attention to critical analysis of the politics of difference as a key issue in the forms that participation in the US can and should take, the politics of exclusion as they play out in such fora, and how the body

politic can be shaped by multi-cultural, multi-vocal participation (Rayner 2003). This work contributes to that conversation by asking about the gendering of technological debate in public forums, while also attending to other categories of difference.

Public opinion surveys in the US (e.g., National Science Board 2006) and UK (Mori-OST 2005) have indicated a consistent pattern of generally positive views of science and technology (S&T), or technological optimism, even in the absence of claimed knowledge about S&T. Familiarity with nanotechnology in the US and elsewhere has been assessed in a number of public opinion surveys (e.g., Burri and Bellucci 2008; Cobb 2005; Currall et al. 2006; Einsiedel 2005; Fujita 2006; Gaskell et al. 2005; Hart 2006; Hart 2007; Kahan et al 2007, 2008, 2009; Lee, Scheufele and Lewenstein 2005; Macoubrie 2006; Priest 2006, 2008; Royal Society 2004; Scheufele et al. 2007, 2009; Siegrist et al. 2007, 2008; Sims-Bainbridge 2002).

At a slightly finer grained analysis, however, a 'White male effect' has emerged quite consistently in the US and elsewhere—i.e., younger, white, better educated males consistently demonstrate higher acceptance, higher perceived benefit, and lower perceived risk of S&T in general, and many technologies in specific (Flynn, Slovic & Mertz 1994; Satterfield, Mertz & Slovic 2004; Satterfield 2008). Satterfield's 2004 restudy of the issues first raised in Flynn, Slovic and Mertz (1994) provides an excellent graphic representation of their findings of consistent gender and race differences in responses to a wide range of technologies (Figure 1):

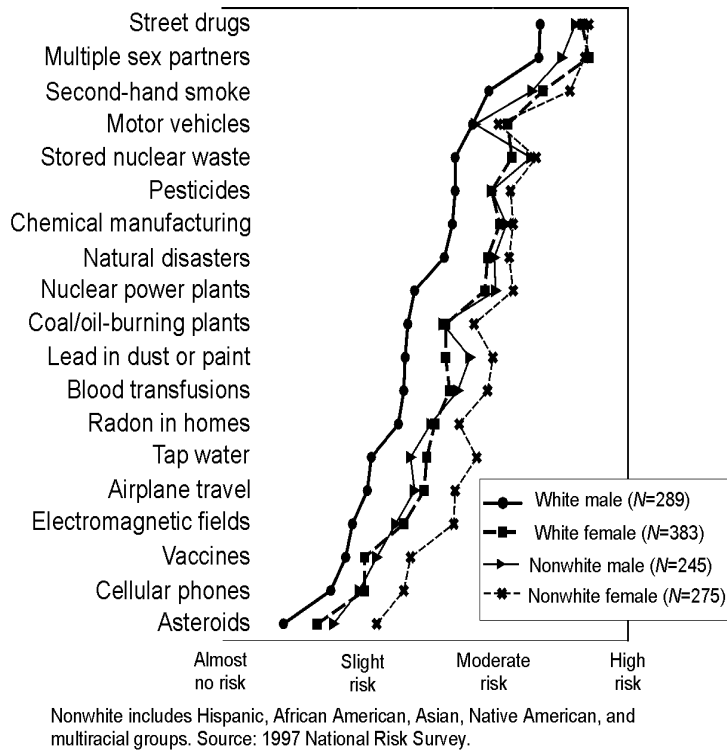


Figure 1: Satterfield, Mertz and Slovic 2004: 118

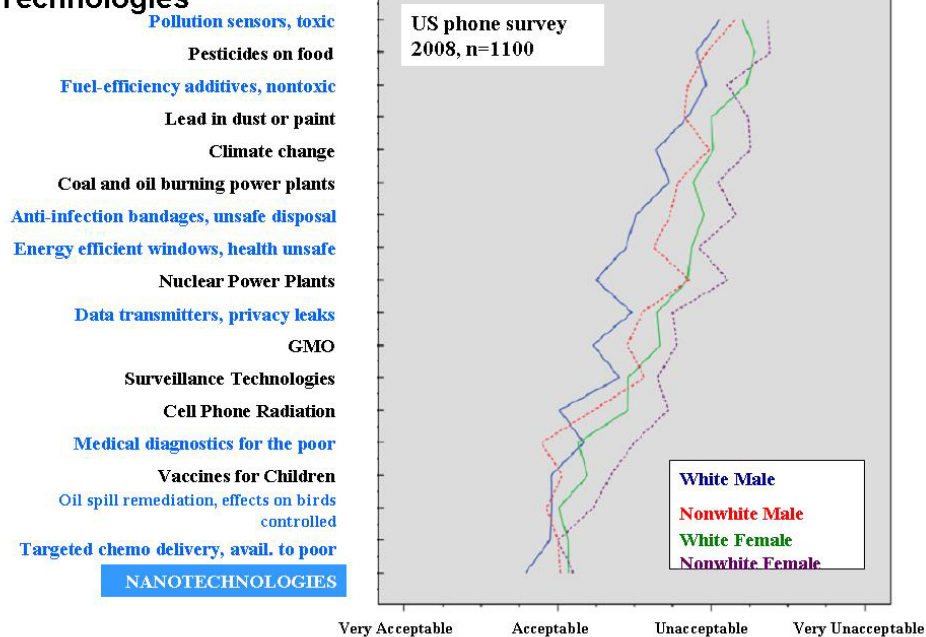
One way to state this is that women and people of color tend to be less accepting, less positive about realizing the benefits of technology, and to display higher perception of risk. The other, possibly more appropriate analysis, is that white men consistently

attenuate risk, demonstrating a distinctive response pattern from all others. The figure also illustrates the intersections of gender and race, as the judgments of white men are widely different from those of nonwhite females (the extreme left and extreme right lines, respectively), but clearly white females' and nonwhite males' responses are more difficult to distinguish and are literally intertwined.

We would expect there to be further complications of the interactions of gender and race if 'nonwhite' were broken out into its constituent, self selected identities.

Nanotech survey research to date, including our own at the CNS, is consistent with this pattern. Nanotech risk perception appears to reproduce the same kinds of patterns of gendered (and raced) differentiation among public participants across an array of nanotech and non-nanotech risk objects, or technologies.

Gender, Race & Acceptability of Nano- & Non-Nano Technologies



Satterfield, Pidgeon, Conti, & Harthorn, in preparation, 2009

Figure 2: Satterfield, Conti, Pidgeon & Harthorn, in prep, 2009

People see generic nanotechnologies (at the bottom—whatever that actually is in public conceptions) as more acceptable, posing relatively lower risk, and with smaller distinctions among respondents in these views, but when contextual details are added on both the benefit side (e.g., medical diagnostics technology—lab on a chip—that can benefit the poor) and especially on the risk side (e.g., pollution sensors that may be toxic in the environment to some species of plants or animals), the same kind of patterned response found in the earlier studies emerges.

Satterfield, Mertz and Slovic (2004) cite earlier literatures on gender and technological risk perception (e.g., Davidson and Freudenburg 1997; Flynn, Slovic and Mertz 1994; Gustafson 1998) and add to the analysis the concept of vulnerability and experiences of discrimination as explanatory mechanisms for gender differences in reported risk perception rather than more essentialized ideas about women and technology, women

and familism, and so on. However, there has been surprisingly little discussion outside the risk perception world of these patterns of intersection of gender and race nor of their implications for equitable public participation in dialogue and debate about technological development and technoscientific futures.

International feminist research on women in science and technology education and the S&T workplace provides ample evidence for highly gendered processes through which both men and women and boys and girls view males as more knowledgeable and competent in math, science & technology, regardless of measured competency, and both men and women similarly underestimate the abilities of women (Fox 2001, 2006; Fox, Johnson and Rosser 2006; Kvande 1999). Digital divide analyses similarly find that women and people of color have had distinct patterns of both *access* and *use* of technologies, particularly information technologies (Leggon 2006; Light 1999; Wajcman 1991). Feminist history of science has contributed a robust reassessment of the ways technology both constructs gender and is constructed by it (e.g., Cowan 1979, 1983; Horowitz 2001; Lerman, Mohun & Oldenziel 1997; Lerman, Oldenziel and Mohun, 2003; MacKenzie and Wajcman 1999; Oldenziel 1999, 2001; Pursell 2001; Rossiter 1980). Cultural anthropologists contribute a large literature on feminism and technology that has explored cross-cultural and historical interactions of gender and technology (e.g., Bray 2007), a critical literature on the social construction and remaking of technoscience (e.g., Landecker 2007; Franklin 2007; Marcus 1995) and of bodies as the site of critical technological engagements (e.g., Lock & Farquhar 2007).

Gender and public participation

While there are a number of possible modes of citizen engagement in the debate of S&T (Dietz and Stern 2008), the deliberative forum has emerged recently as a key mode in public engagement in Europe, particularly the UK (Doubleday 2007; Kearns, Macnaghten and Wilsdon 2006; Laurent 2007; Leach, Scoones and Wynne 2005; Pidgeon & Rogers-Hayden 2007; Wilsdon 2005; Wilsdon and Willis 2004; Wynne, Wilsdon and Stilgoe 2005), with 'upstream' (and now, 'midstream') engagement a new aim in the nanotechnology context. 'Upstream' refers to involvement of public early in the R&D process—in the nanotech case this means while products are still literally on the drawing boards—with the aim of pursuing public dialogue *before* irrevocable decisions have been made. The foundational report by the Royal Society (2004) identified three ways that developments in nanotechnology can be considered upstream: first, many of the future trajectories of nanotechnology have yet to be decided; second, many questions remain about the potential social and ethical impacts; and three, awareness of nanotechnology is fairly low and public acceptance of nanotechnology is not yet determined. Arguably all three of these conditions still obtain.

Upstream deliberation is proving complex and difficult in a number of respects. Woodrow Wilson's Project on Emerging Nanotechnologies currently lists over 1000 nanotech products already in the marketplace (for example, in cosmetics, sunscreens, textiles, sporting equipment, electronics, construction and building materials, and food—see Project on Emerging Nanotechnologies), which does refute how 'early' in development engagement is taking place. However, the complexity of the nanoenterprise, the large number of possible nanomaterials, applications, and domains involved, and the differing timelines for their development and commercialization all make freeze-framing any part of the nanoenterprise for deliberation impossible to contemplate (Renn and Roco 2006). Discussion of yet-to-be invented products is providing novel challenges in social research. In any case, the EU has a growing portfolio of model citizen engagement

processes, some with direct links to policymakers. By sharp contrast, the US has no comparable framework for such interactions, and in particular has no such direct links to policymakers, and, as we found in our research, little cultural knowledge in circulation about how such mechanisms would work. Univ. of South Carolina (Besley, Kramer et al. 2008; Tuomey 2006; Tuomey and Baird 2006), Univ. of Wisconsin (Kleinman and Powell 2005), and the CNS at ASU, through their partner, North Carolina State College (Hamlett, Cobb and Guston 2008), in addition to our cross-national study (Pidgeon, Harthorn et al. 2009), have explored different models for engagement, with CNS-UCSB's most closely modeled on the UK deliberative forum.

As one measure of the capacity of US citizens for deliberation, Cook et al. (2007) study the amount of participation in public meetings and other forms of political talk in the US and in 2003 they found that 25% of citizens reported attending one or more meetings in the past year (this is a loose standard for engagement). Eighty five percent of those who did not attend were not invited to one. Participants were more educated and affluent than non-attenders and 69% had some college experience. So it is fairly clear that familiarity with deliberative type meetings is not well distributed across more diverse sectors in US society. Public participation at NISEnet public forums would be another example of selective public participation, and increasing diversity is a major aim of the NISEnet in its future work. In addition, engagement intended at forming consensus for decision making expressly submerges standpoints of individuals with minority views and the race/class/gender/sexuality and other social locational features that are of critical importance in the large, multicultural, multiethnic US context. Exploring this *conundrum of consensus and difference* and bringing difference to the table is at the heart of our approach.

Gastil (2008) argues that deliberation makes democracy work. His general definition of deliberation is: 1) create a solid information base; 2) prioritize the key values at stake; 3) identify a broad range of solutions; 4) weigh the pros, cons, and trade-offs among solutions; and 5) make the best decision possible. Drawing from both Habermas and Barber, he explores the ranges of kinds of 'talk' that contribute to deliberative outcomes (including never reaching a decision). Key to this approach on deliberation are the importance of opposition in the development of themes and counterthemes and the group's use of available resources including both media and personal experiences (Gastil 2008:23). Ideally, deliberation operates in a space that brings together people from diverse sectors of society, allows everyone to have an equal say, and forces participants to recognize the needs of others in the group, but there are many impediments to this, including group dynamics (Mendelberg and Karpowitz 2007).

Gender as a factor in deliberation has drawn surprisingly little attention (for one exception, see Hickerson and Gastil 2008), although there is some suggestive evidence from studies of focus groups. Women's studies methods scholars have noted competing effects of focus group participation on women with opportunities for empowerment and for discomfort (Anderrson and Roche 2006; Jowett and O'Toole 2006; Wilkinson 1999). More essentialized arguments about feminine nature or socialized tendencies are often invoked to explain women's behavior, rather than gendered processes and positionality. For example, one study argues that women are more likely to empathize, "to emphasize interdependence, to choose egalitarian solutions, and to use a democratic leadership style; men in turn tend to emphasize autonomy and to behave hierarchically" (Mendelberg and Karpowitz 2007:107). Group norms also are argued to play a role, with male dominated groups displaying masculine norms, and female dominated group

feminine norms. Hollander (2004) has also focused on the social context for focus groups as a key factor in how status issues play out, although the self-management style she advocates would be more difficult to implement in the deliberative setting. More complex issues about intersections of gender with race and class are absent from these literatures, although they abound in feminist studies, women's studies, cultural studies, and other social sciences (e.g., Crenshaw 1991; Mann and Huffman 2005; Segal and Martinez 2007).

CNS-UCSB Deliberation Research

This project is part of a comparative US-UK cross national study intended to look at national differences in perceptions of benefits and risks to new nanotechnology applications for health and human enhancement, and for energy. We chose these two application types anticipating they would elicit different responses in order to highlight contextual differences as factors in emergent risk judgments. To do this research, the aim was to develop a single workshop approach that would be more limited in time and resources than elaborate reconvened or citizen jury models (Pidgeon, Harthorn, & Satterfield 2009). We constructed a lengthy workshop format for focus group sized groups (n=12-15), developed a protocol we could use reliably across sites (and nations) for a set of staged discussions about health, energy, technologies for each, and risks and benefits of these new technologies about which participants knew almost nothing coming into the sessions. The 4.5 hour long workshops included both large group discussion (12-15 participants, plus 3 facilitators) and small "world café" discussion tables (4 participants, plus 1 facilitator). All dialogue was audio recorded, and the larger group discussions were video recorded as well. Participants were recruited 'blind' to the nanotechnology focus of the workshops, and we collected simple pre- and post-workshop data about their familiarity with and knowledge of nanotechnology. The methodology allows us to track individuals throughout the deliberative session and to assess group level dynamics such as polarization as well (e.g., Hamlett and Cobb 2006; Sunstein 2002).

We piloted and extensively modified the protocol three times, and then ran four parallel workshops in Feb 2007, two in each country covering the two applications. Participants were carefully recruited to match local demographics as closely as possible and to balance gender, but gender was not a main focus of this stage of the research. We later developed verbatim transcripts of the workshops and have analyzed them extensively using qualitative data analysis software and a collaborative, interpretive method. The initial main findings from this study were published in *Nature Nanotechnology* in February 2009 (Pidgeon, Harthorn et al. 2009).

To summarize in brief, the study found a robust benefits frame, even in the UK, about nanotechnologies for both health and energy. The US and UK groups were far more similar than different in their responses. The responses to the different application contexts, however, were more emphatically different, in both countries—energy applications were seen far more positively than health and enhancement applications. However, the questions about health and enhancement applications were not primarily about *lack of perceived benefit* but rather about *social risks* such as distributional justice and organizational "recreancy" (Freudenburg 1993) about the ability and inclination of both governments and industry to safely and ethically manage them for the greater good. UK respondents expressed more concern about government's failings; US respondents excoriated corporations' greed and profit motives.

In addition to the main findings about application context and cross-national differences, we did trace a number of highly suggestive findings regarding gender. That there are gender differences would not be surprising (in fact, it would be far more surprising if there were not), but the absence of detailed analysis of gender effects in public participation makes these more significant, and we have used these as the basis for a new project funded by NSF that is exploring these more systematically (Harthorn, with Bryant and Rogers 2008).

First, gender and ethnicity (along with age) appeared to interact to produce distinctive patterns of discourse in the deliberative context. We saw these in terms of who talked more, who talked earlier in the workshop overall and in the individual sections, who initiated responses in the group discussion, the length and number of utterances (total number of words), and who dominated discussion, with these operating in the predicted direction. That is, white male participants asserted themselves in seizing and shaping the discussion early, and claiming relatively more ownership of the domain and discussion. And women and participants of color were as a consequence relegated to (or opted for) a more minor role. Actual knowledge of nanotechnologies appeared to play little role in this process of differentiation; but interest in S&T as well as cultural constructions of masculinity (and femininity) very likely contribute to the pattern.

In addition, group size mattered quite a lot to modes of participation. The workshops included both large group discussion (12-15 participants, plus 3 facilitators) and small “world café” discussion tables (4 participants, plus 1 facilitator). Women participants and participants of color were more vociferous, and seemed more comfortable and more assertive in the smaller group context, disrupting the white male effect observed in the larger group with their participation. These effects did not seem to carry back into the larger group discussion that followed, however.

Perceptions of nanotech benefits and risks did not split neatly down gender lines, however there were marked tendencies, strongly affected by age as well, consistent with other predictions. Both men and women were generally positive about new nanotechnologies themselves. However, women raised a different array of issues around risks, were impressed differently by specific expected benefits and technoscientific promises more generally. These differences were more pronounced in the health application discussion, and more muted in the context of energy technologies. The latter elicited more unanimous support, with perception of urgency seeming to drive high expressed acceptance.

Consistent with feminist literatures and survey literature on public opinion and risk perception, gender seemed in this first round of workshops in 2007 to drive distinct assumptions about *who will benefit* and *what the benefits will be*. Locus of benefit as well as locus of potential harm (individual, family, community, or wider society) also seemed to be operating, although cross-national differences were possibly confounding this. Also consistent with expectations, women and participants of color more consistently expressed more concern than did white men about the potential role of nanotechnologies in exacerbating social inequalities. This was primarily articulated as a distributional justice issue, directly connected to the ‘who will benefit’ question. Nanotech medical technologies, thus, widely viewed by experts as likely to gain public support, actually were controversial in our workshop dialogues because of concerns about who would actually have access to them. High cost was the main factor in this, and it

operated on the UK side as well as the US. Issues of trust about the social contract or environmental health and safety issues, of great importance in technological risk perception, seemed to be gendered as well, with different issues, expectations and assumptions voiced by men and women about governments', corporations', and communities' ability and likelihood to manage technologies wisely and for social benefit. For example, women in both US and UK contexts were the ones who initiated a discussion of distrust of corporations.

The results from the first workshops can only be suggestive, given the small group size, small overall sample sizes, cross-cultural split of those small samples, and the baseline nature of that study. In response to those suggestive findings, however, we developed a new study, funded by the National Science Foundation in 2008, to focus on gender effects in the nanotech deliberative context. The new study is looking at gender as a between group variable in a 2 by 3 design with the same two application conditions (energy/environment and health/enhancement) on which we have already collected baseline data and for each, three gendered groups of women only, men only, and mixed gender.

2009 Workshops	ENERGY/ ENVIRONMENT	HEALTH/ ENHANCEMENT
Women only	1	1
Men only	1	1
Mixed W/M	1	1

Fig. 3: 2009 CNS-UCSB Deliberative Workshops

The focus group-size groups (n=12-15) will in all other respects be recruited and composed on a stratified quota sample basis to be as comparable as possible and to reproduce the local California demographics regarding race/ethnicity, age, and education/income/occupation. Although largely consistent with the 2007 workshop format, updates to the protocol and informational materials we provide for the World Café-type discussions have necessitated two pilot workshops, before running the six groups in September-October 2009. We are holding these in the central coastal California area in order to maintain comparability with the 2007 study. At this writing we have held one health/enhancement pilot (July 2009), and the second pilot on energy/environment applications plus six workshops are scheduled to take place over the next month (September-October 2009). We therefore do not yet have data from the new study to report for this paper.

While we are looking in this research at gender as a between group variable, our intersectional approach means we will be closely examining the transcripts and videos for possible race/ethnicity effects within groups as well and anticipate following this 2009 study in 2011 with a between groups study of race/ethnicity. The intersectional approach argues the importance of considering the ways experiences of gender, race, class, immigration status and other categories of difference act in concert to produce distinct positions of subjectivity, identity, and hence of positionality.

Making sense of gendered technological perceptions and dialogue

Competing theories about public opinions and attitudes regarding nanotechnologies (and S&T more generally) emphasize not the participants' backgrounds and lived experience but rather the effects on individuals of how information is framed, sequenced, and delimited (Nisbet 2009; Nisbet, Scheufele et al. 2002), the media frames themselves (Friedman and Egolf 2005, 2007; Weaver and Bimber 2008; Weaver, Lively and Bimber 2009), and cultural ideological tuning between information sources and recipients (Kahan et al. 2007, 2008, 2009). Another large stream of literature attributes variance in public responses regarding new technologies to differentially distributed scientific literacy, knowledge & understanding, citing knowledge deficits as the main impediment to public acceptance of new technologies (reviewed in Sturgis and Allum 2004). The "white male effect" and more broadly the politics of difference have been largely ignored or missed in existing analyses. As a possible remedy to these blind spots, we propose other interpretive frameworks. An intersectional feminist perspective (as well as an interpretive anthropological/sociological one) leads us to assume that the predispositions, interests, and beliefs people bring with them to a deliberative context, including gender and ethnic identities, educational background, occupation, and age, personal histories and lived experiences, as well as cultural values and interpretive frameworks all should affect and shape their responses to the new ideas presented in nanotechnology workshops. For example, Satterfield's survey work (2004) has argued that rather than experiences of motherhood (an essentialist feminist argument), it is instead experiences of vulnerability and perceived injustice that better explain gender and race/ethnicity differences in technological risk perception. Baseline understandings about health, energy and the future also play a role, and other psychological, social, and contextual factors.

Feminist research and writing on technoscience intersections offer particular insights to these issues, although not at all are integrated into the empirical quantitative research world of risk perception. The rich feminist literature on the role of technoscience in the constructions of difference-- bodies that matter (Judith Butler); discourse of difference (Emily Martin); cyborg ontology (Donna Haraway); and gender identities (Karl Bryant)— provides interpretive strength, as does the literature on lived experience in technological context (Marcia Inhorn; Michel de Certeau, Judith Farquhar, Nancy Miller, and others; see Lock and Farquhar 2007). Also this critique of national projects of participation can draw on the rich literature on colonial sites of marginalization, cooptation and control (Patricia Kaufert & John O'Neil; Nancy Scheper-Hughes,), and the commodification and control of bodies (Margaret Lock, Nancy Scheper-Hughes, Aihwa Ong, etc). All of these provide more nuanced analysis of the complex interactions, histories and precipitating factors that produce particular gendered responses to and co-production of nanotechnologies.

The literature on social and cultural factors in health inequality and health risk provides important contextual understanding of unfolding responses to nanotechnologies for health (and enhancement). Issues about who will benefit and who will be harmed in the US reflect deep histories of racialization and social differentiation (Harthorn and Oaks 2003). Citizens' concerns about access to expensive new technologies are highlighted in the current political debate in the US but are reflected in epidemiological and socio-cultural realities (Krieger 2005).

Although the research on gender and nanotechnology is new, it draws heavily on feminist research in S&T studies and highlights gender differences in cultural beliefs about technology. Analysis of nanotechnology in a global context complicates Western cultural assumptions about gender, technology, and risk perception because the relationship between gender and technology differs according to region and culture. Research on nanotechnology in a more global context offers potential opportunities to study how nanotech is part of another set of divisions and how it also offers promise to erase some of these divisions. A critical feminist analysis of the global nano-enterprise highlights the potential for an increase in global inequalities regarding access to and involvement in decision-making, development, research, and application of nanotechnologies as they affect indigenous populations and women in developing countries. Feminist theories of women and development grapple with how to understand the role of women within development projects and the relationship between gender, agency, culture, the environment (Bhavnani, Foran, and Kurian 2003; Jaquette and Staudt 2006). Development projects often subordinate women and culture to the process of economic development. Therefore, the promise nanotechnology within development projects (i.e. water purification, nutritional improvements in food, and agricultural projects) occur within the complex world of development projects that vary in their active involvement of women and community members. Although this paper has primarily discussed public engagements in the US and UK, but examples of citizen forums and discussions on technology occur across the globe, including developing countries. How might public engagement and the question of difference play out differently in other countries? In addition to the question of citizen engagement, it is important to consider how accessible/affordable new consumer projects are, especially those that could affect great change in poor communities.

In our current research we aim to use qualitative research and the insights it can provide in the social and cultural production of meaning (Friedland and Mohr 2004) to gain understandings that can then be tested more systematically in future survey research. We aim in the current study to disentangle the effects of participation in the process of nanotech deliberation from some of the key social locational aspects of the individual participants. This work asks: how much change (or intensification) in views does participation in deliberative nanotechnology forums produce—or not produce—for whom, under what conditions, looking very carefully at group processes of marginalization as well as consensus building. Further, we ask: Do the emergent nature of the views and the quasi-political context of deliberation interact in identifiable ways? And what are the implications of these for the national project of *equitable* public participation in technology and science? The research in progress cannot yet provide answers to those questions, but we argue strongly that nanoethics needs to embrace them as important aspects of the societal impacts of new nanotechnologies.

References

- Anderrson, N. and M. Roche. 2006. Gender and evidence-based planning: the CIET methods. *Development in Practice* 16(2): 141-152.
- Bhavnani, K.-K., Foran, J., and Kurian, P. Eds. 2003. *Feminist Futures: Re-imagining Women, Culture and Development*. New York: Zed Books.
- Bhavnani, K.-K., Foran, J., and Talcott, M. 2005. The red, the green, the black, and the purple: Reclaiming development, resisting globalization. *Critical Globalization Studies*, eds. R.
- Appelbaum and W. Robinson. New York: Routledge.
- Besley, J. C., V. L. Kramer, et al. 2008. Interpersonal discussion following citizen engagement about nanotechnology: What, if anything, do they say? *Science Communication* 30: 209-235.
- Bray, F. 2007. Gender and technology. *Annual Review of Anthropology* 36:37-53.
- Burri, Regula V. and Sergio Bellucci. 2008. Public perception of nanotechnology. *Journal of Nanoparticle Research* 10: 387-391.
- Cobb, Michael D. 2005. Framing effects on public opinion about nanotechnology. *Science Communication* 27(2): 221-239
- Cook, F. L., M. X. D. Carpini, et al. 2007. Who deliberates? Discursive participation in America. In *Deliberation, Participation, and Democracy*. Ed. S. W. Rosenberg, pp. 25-44. Hampshire, England: Palgrave Macmillian Publishers.
- Cowan, Ruth Schwartz. 1979. "From Virginia Dare to Virginia Slims: Women and technology in American life." *Technology and Culture* 20(1):51-63.
- Cowan, Ruth Schwartz. 1983. *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*. New York: Basic Books.
- Crenshaw, Kimberlé. 1991. Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stanford Law Review* 43(6): 1241–1299.
- Currall, Steven C., Eden B. King, Neal Lane, Juan Madera, and Stacey Turner. 2006. What drives public acceptance of nanotechnology? *Nature Nanotechnology* 1: 153–155.
- Davidson, D. and W. Freudenburg. 1997. Gender and environmental risk concerns: A review and analysis of available research. *Environment and Behavior* 28: 302-339.
- Dietz, T. and P. C. Stern. 2008. *Public Participation in Environmental Assessment and Decision Making*. Washington, DC: National Research Council of the National Academies.
- Doubleday, R. (2007). "Risk, public engagement and reflexivity: Alternative framings of the public dimensions of nanotechnology." *Health, Risk & Society* 9(2): 18.

Einsiedel, Edna. 2005. In the public eye: The early landscape of nanotechnology among Canadian and U.S. publics. AZojono online publication Dec 30.
<http://www.azonano.com/Details.asp?ArticleID=1468>

Erikson, Kai. 1994. *A New Species of Trouble: The Human Experience of Modern Disasters*. New York: Norton.

Flynn, James, Paul Slovic, and C.K. Mertz. 1994. Gender, race, and perception of environmental health risks. *Risk Analysis* 14(6):1101-1108.

Fox, Mary Frank. 2001. Women, science and academia: Graduate education and careers. *Gender and Society* 15 (5) October: 654-666

Fox, Mary Frank. 2006. Women, men, and engineering. In *Women, Gender, and Technology*, Eds., M. F. Fox, D. Johnson, and S. Rosser. Urbana: University of Illinois Press.

Fox, Mary Frank, Deborah Johnson, and Sue Rosser, eds. 2006. *Women, Gender, and Technology*. Urbana: University of Illinois Press.

Franklin, Sarah. 2007. *Dolly Mixtures: The Remaking of Genealogy*. Durham: Duke Univ. Press.

Freudenburg, William. 1988. Perceived risk, real risk: Social science and the art of probabilistic risk assessment. *Science* N.S. 242(4875): 44-49.

Freudenburg, Willam. 1993. Risk and recreancy: Weber, the division of labor, and the rationality of risk perceptions. *American Journal of Sociology* 71(4):909-932.

Freudenburg, William. 1996 Risky thinking: Irrational fears about risk and society. *Annals of the American Academy of Political and Social Science* 454(1):44-53.

Friedland, Roger and Mohn Mohr, eds. 2004. *Matters of Culture: Cultural Sociology in Practice*. New York: Cambridge Univ. Press.

Friedman, Sharon and Brenda P. Egolf. 2005. [Nanotechnology: Risks and the media](#). *IEEE Technology and Society Magazine*, Winter, 2005: 5-11.

Friedman, Sharon and Brenda Egolf. 2007. Changing patterns of mass media coverage of nanotechnology risks. Presentation by Sharon M. Friedman, Woodrow Wilson International Center for Scholars, Project on Emerging Nanotechnologies, Washington, D.C., 12/18/07. Accessible from:
http://www.lehigh.edu/~smf6/nanotechnology_research.html

Fujita, Y. 2006. Perception of nanotechnology among general public in Japan. *Asia Pacific Nanotech Weekly* 4, article #6:1-2. Available at:
www.nanoworld.jp/apnw/articles/library4/pdf/4-6.pdf

Gaskell, George, Toby Ten Eyck, Jonathan Jackson and Giuseppe Veltri. 2005. Imagining nanotechnology: cultural support for technological innovation in Europe and the United States. *Public Understanding of Science* 14: 81-90.

Gastil, John. 2008. *Political Communication and Deliberation*. Thousand Oaks, CA: Sage Publications.

Gastil, J., L. Black, et al. 2008. Ideology, attitude change, and deliberation in small face-to-face groups." *Political Communication* 25(1): 23 - 46.

Gustafson, Per E. 1998. Gender differences in risk perception: Theoretical and methodological perspectives. *Risk Analysis* 18(6): 805-811.

Hamlett, P. W. and M. D. Cobb. 2006. Potential solutions to public deliberation problems: Structured deliberations and polarization cascades. *The Policy Studies Journal* 34(4): 21.

Hamlett, Patrick, Michael Cobb, and David Guston. 2008. *National Citizens' Technology Forum Report: Nanotechnologies and Human Enhancement*. CNS-ASU Report #R08-0002. Tempe, AZ: Center for Nanotechnology in Society at ASU.
<http://cns.asu.edu/files/NCTFSummaryReportFinalFormat08.pdf>

Hart, Peter D. Research Associates, Inc. 2006. *Report Findings*. (Sept. 19) Available at http://www.nanotechproject.org/file_download/files/HartReport.pdf.

Hart, Peter D. Research Associates, Inc. 2007.
http://www.nanotechproject.org/news/archive/poll_reveals_public_awareness_nanotech/

Harthorn, B. H. and L. Oaks, eds. 2003. *Risk, Culture, and Health Inequality: Shifting Perceptions of Danger and Blame*. Westport, CT: Praeger/Greenwood.

Harthorn, Barbara Herr, Karl Bryant, Terre Satterfield and Milind Kandlikar. 2007. Nano expert attenuation in the age of upstreaming. Paper presented at the Society for the Social Study of Science (4S), Montreal, Oct. 11.

Harthorn, Barbara Herr and Karl Bryant. 2008. The "white male effect" and gendered risk beliefs about emerging nanotechnologies in the US. Paper presented in the session on New Technologies, Gendered Meanings, and Social Inequalities, American Anthropological Association annual meetings, San Francisco, CA Oct. 20.

Harthorn, Barbara Herr (with Karl Bryant and Jennifer Rogers). 2008. Deliberating Nanotechnologies in the US: Gendered Beliefs about Benefits and Risks as Factors in Emerging Public perception and Participation. NSF SES-0824042, Principal Investigator, Harthorn, 2008-2010.

Hickerson, A. and J. Gastil. 2008. Assessing the difference critique of deliberation: Gender, emotion, and the jury experience. *Communication Theory* 18: 28.

Hollander, J. 2004. The social contexts of focus groups. *Journal of Contemporary Ethnography* 33(5): 602-637.

Horowitz, R. (ed). 2001. *Boys and Their Toys: Masculinity, Class and Technology in America*. New York: Routledge.

Internet World Stats. 2007. United States of America: Internet Usage and Broadband Usage Report. Internet World Stats: Usage and Population Statistics. Retrieved October 27, 2007 (<http://www.internetworldstats.com/am/us.htm>).

Irwin, Alan and Brian Wynne, eds. 1996. *Misunderstanding Science? The Public Reconstruction of Science and Technology*. Cambridge: Cambridge Univ Press.

Jaquette, J. S., and Summerfield, G., Eds. 2006. *Women and Gender Equity in Development Theory and Practice: Institutions, Resources, and Mobilization*. Durham and London: Duke University Press.

Jowett, M. & G. O'Toole. 2006. Focusing researchers' minds: Contrasting experiences of using focus groups in feminist qualitative research. *Qualitative Research* 6(4):453-472.

Kahan, Daniel M., Paul Slovic, Donald Braman, John Gastil and Geoffrey Cohen. 2007. Affect, values, and nanotechnology risk perceptions: An experimental investigation. (March 7, 2007). *GWU Legal Studies Research Paper* No. 261 Available at SSRN: <http://ssrn.com/abstract=968652>.

Kahan, Daniel M., Paul Slovic, Donald Braman, John Gastil, Geoffrey Cohen and Douglas Kysar. 2008. Biased assimilation, polarization, and cultural credibility: An experimental study of nanotechnology risk perceptions. PEN Research Brief No. 3, Feb. Available at: http://www.pewtrusts.org/our_work_report_detail.aspx?id=34882

Kahan, Daniel, Donald Braman, John Gastil, Paul Slovic and Geoffrey Cohen. 2009. Cultural cognition of the risks and benefits of nanotechnology. *Nature Nanotechnology* 4:87-90.

Kearnes, Matthew, Phillip Macnaghten, P. and James Wilsdon. 2006. *Governing at the Nanoscale: People, Policies and Emerging Technologies*. London: Demos.

Kleinman, Daniel and Maria Powell. 2005. *Report of the Madison Area Citizen Consensus Conference on Nanotechnology*, http://www.nanocafes.org/files/consensus_conference_report.pdf

Krieger, N. (ed.). 2005. *Embodying Inequality: Epidemiological Perspectives*. Amityville, NY: Baywood Publishers.

Krimsky, S. & Golding, D., eds. 1992. *Social Theories of Risk*. Greenwood Press.

Kvande, E. 1999. "In the belly of the beast:" Constructing femininities in engineering organizations. *European Journal of Women's Studies* 6(3):305-328.

Landecker, Hannah. 2007. *Culturing Life*. Cambridge: Harvard University Press.

Laurent, Brice. 2007. Diverging convergences: Competing meaning of nanotechnology and converging technologies in a local context. *Innovation: The European Journal of Social Science Research* 20: 343-357.

- Leach, Melissa, Ian Scoones, and Brian Wynne, eds. 2005. *Science and Citizens: Globalization and the Challenge of Engagement*. London: Zed Books.
- Lee, Chul-Joo, Dietram Scheufele and Bruce Lewenstein. 2005. Public attitudes toward emerging technologies. *Science Communication* 27(2): 240-267.
- Leggon, C.B. 2006. Gender, race/ethnicity, and the digital divide. In *Women, Gender, and Technology*, M.F. Fox, D.G. Johnson and S.V. Rosser, eds., pp. 98-110. Urbana: Univ of Illinois Press.
- Lerman, N. E., A.P. Mohun and R. Oldenziel, eds. 1997. Gender analysis and the history of technology. Special issue, *Technology and Culture*, 38(1).
- Lerman, Nina, Ruth Oldenziel, and Arwen Mohun, eds. 2003. *Gender & Technology: A Reader*. Baltimore: Johns Hopkins Univ Press.
- Light, Jennifer S. 1999. When computers were women. *Technology and Culture* 40(3):455-483.
- Lichtenstein, S. and Slovic, P., editors. 2006. *The Construction of Preference*. New York: Cambridge University Press.
- Lock, Margaret and Judith Farquhar, Eds. 2007. *Beyond the Body Proper: Reading the Anthropology of Material Life*. Durham: Duke Univ. Press.
- MacKenzie, D. and J. Wajcman (eds). 1999(1985). *The Social Shaping of Technology: How the Refrigerator Got its Hum*. UK: Milton Keynes, UK.
- Macnaghten, P., M.B. Kearnes, & Brian Wynne. 2005. Nanotechnology, governance, and public deliberation: What role for the social sciences? *Science Communication* 27(2): 268-291
- Macoubrie, Jane. 2006. Nanotechnology: public concerns, reasoning and trust in government. *Public Understanding of Science* 15: 221-241.
- Mann, S.A and D. J. Huffman. 2005. The decentering of second wave feminism and the rise of the third wave. *Science and Society* 69(1): 56-91.
- Marcus, G.E., ed. 1995. *Technoscientific Imaginaries*. Chicago: University of Chicago Press.
- Mendelberg, Tali and Christopher F. Karpowitz. 2007. How people deliberate about justice. In *Can the People Govern?*, ed. Shawn Rosenberg, pp. 101-129. Basingstoke, UK: Palgrave Macmillan.
- Mexican Internet Association. 2007. Estudio de Habitos de Usarios en Internet 2007/Mexican Internet Association. Retrieved October 26, 2007. [http://amipci.org.mx/temp/pdf-0315967001193426740OB.pdf. /](http://amipci.org.mx/temp/pdf-0315967001193426740OB.pdf./)

Mori-OST. 2005. *Science in Society: Findings from Qualitative and Quantitative Research*. London: Office of Science and Technology.

National Nanotechnology Initiative (NNI), n.d.(a) What is nanotechnology? Downloaded 1/29/09 from: <http://www.nano.gov/html/facts/whatIsNano.html>

National Nanotechnology Initiative (NNI), n.d.(b) Applications and products. Downloaded 1/29/09 from: <http://www.nano.gov/html/facts/nanoapplicationsandproducts.html>

National Science and Technology Council. 2008. NNI: Strategy for Nanotechnology-Related Environmental, Health, and Safety Research. Committee on Technology: Subcommittee on Nanoscale Science, Engineering, and Technology. February. http://www.nano.gov/NNI_EHS_Research_Strategy.pdf

National Science Board. 2006. Science and technology: Public attitudes and understanding. In *Science and Engineering Indicators. /National Science Foundation/,ch 7, 1-46*. <http://www.nsf.gov/statistics/seind06>.

Nisbet, M.C. 2009, *in press*. Framing science: A new paradigm in public engagement. *Understanding Science: New Agendas in Science Communication*, L. Kahlor & P. Stout (eds.). New York: Taylor & Francis.

Nisbet, M. C., D. A. Scheufele, J. E. Shanahan, P. Moy, D. Brossard, and B. V. Lewenstein. 2002. Knowledge, reservations, or promise? A media effects model for public perceptions of science and technology. *Communication Research* 29(5):584–608.

Oldenziel, Ruth. 1999. *Making Technology Masculine: Men, Women, and Modern Machines in America, 1870-1945*. Amsterdam:

Oldenziel, Ruth. 2001. Man the maker, woman the consumer: The consumption junction revisited." In *Feminism in Twentieth-Century Science, Technology and Medicine*, A.N. Creager, E. Lunbeck, & L. Schiebinger, eds, pp. 128-148. Chicago: University of Chicago Press.

Pidgeon, Nicholas, *et al.* 1992. Risk perception. *Risk - Analysis, Perception and Management: Report of a Royal Society Study Group*, Ch. 5, 89-134. London: The Royal Society.

Pidgeon, Nicholas, Roger E. Kasperson and Paul Slovic, eds. 2003. *The Social Amplification of Risk*. Cambridge: Cambridge University Press.

Pidgeon, N.F., W. Poortinga, G. Rowe, T-H Jones, and J. Walls. 2005. Using surveys in public participation processes for risk decision making: The case of the 2003 British GM Nation? public debate. *Risk Analysis* 25(2):467-479.

Pidgeon, Nicholas F. and Tee Rogers-Hayden. 2007. Opening up nanotechnology dialogue with the publics: risk communication or 'upstream engagement'? *Health, Risk and Society* 9: 191-210.

- Pidgeon, Nicholas, Barbara H. Harthorn, Karl Bryant and Tee Rogers-Hayden. 2009. Deliberating the risks of nanotechnologies for energy and health applications in the United States and United Kingdom. *Nature Nanotechnology* 4 (2):95-98.
- Pidgeon, Nick, Barbara Herr Harthorn, and Terre Satterfield. 2009. Understanding public attitudes towards nanotechnologies. *The Chemical Engineer*. Under review.
- Priest, Susanna. 2006. The North American opinion climate for nanotechnology and its products: Opportunities and challenges. *Journal of Nanoparticle Research* 8: 563–568.
- Priest, Susanna. 2008. Media representations of nanotechnology. Presentation in Societal Dimensions of Nanotechnology PI meeting, Arlington VA, NSF Jul 28-29. Project on Emerging Nanotechnologies (PEN), Consumer product inventory, http://www.nanotechproject.org/inventories/consumer/analysis_draft/. Download 1/29/09.
- Pursell, Carroll. 2001. Feminism and the rethinking of the history of technology.” In *Feminism in Twentieth-Century Science, Technology and Medicine*, A.N. Creager, E. Lunbeck, & L. Schiebinger, eds., pp. 113-127. Chicago: University of Chicago Press.
- Rapp, Rayna. 1999. *Testing Women, Testing the Fetus: The Social Impact of Amniocentesis in America*. New York: Routledge.
- Rayner, S. 2003a. Who's in charge? Worldwide displacement of democratic judgment by expert assessments, *Economic and Political Weekly* 38(48):5113-9.
- Rayner, Steve. 2003b. Democracy in the age of assessment: Reflections on the roles of expertise and democracy in public-sector decision making. *Science and Public Policy* 30(3):163-70.
- Rayner, Steve. 2004. The novelty trap: Why does institutional learning about new technologies seem so difficult? *Industry and Higher Education* 18(5): 349-55.
- Renn, Ortwin. 1999. A model of an analytic-deliberative process in risk management. *Environmental Science and Technology* 33(18):3049-3055.
- Renn, Ortwin and Mihail Roco. 2006a. IRGC (International Risk Governance Council): *Nanotechnology – Risk Governance*. White Paper No. 2, annexes by M. Roco and E. Litten. Geneva, IRGC.
- Renn, Ortwin and Mihail Roco. 2006b. Nanotechnology and the need for risk governance. *Journal of Nanoparticle Research*, 8 (2-3): 23-45.
- Rossiter, M. W. 1980. “Women's work” in science, 1880-1910. *Isis* 71(3):381-398.
- Royal Society. 2004. *Nanoscience and nanotechnologies: opportunities and uncertainties*. July 29. London: Royal Society and Royal Academy of Engineering. Downloadable from: <http://www.nanotec.org.uk/finalReport.htm>
- Satterfield, Terre A. 2008. Crude proxies, racializing narratives, and backdoor curiosities: Reflections across a few studies of race, gender, and risk. Paper presented in session on New Technologies, Gendered Meanings, and Social Inequalities, American Anthropological Association meetings, San Francisco, CA, Nov. 20.

Satterfield, Terre, C.K. Mertz, and Paul Slovic. 2004. Discrimination, vulnerability, and justice in the face of risk. *Risk Analysis* 24(1):115-129.

Satterfield, Terre, Milind Kandlikar, Christian Beaudrie, Joseph Conti, and Barbara H. Harthorn. 2009. Anticipating the perceived risk of nanotechnologies. Forthcoming, *Nature Nanotechnology*.

Satterfield, Terre, Joseph Conti, Barbara H. Harthorn and Nicholas Pidgeon. 2009. Malleability, Vulnerability and Stigma in Judgments about Nanotechnology. Work in preparation. Poster presented at CNS-UCSB Research Summit, Santa Barbara, CA, January 19-20.

Scheufele, Dietram A., Elizabeth A. Corley, Tsung-jen Shih, Kajsa E. Dalrymple and Shirley S. Ho. 2009. Religious beliefs and public attitudes toward nanotechnology in Europe and the United States. *Nature Nanotechnology* 4:91-94.

Scheufele, Dietram, Elizabeth Corley, Sharon Dunwoody, Tsung-jen Shih, Elliott Hillback and David Guston. 2007. Scientists worry about some risks more than the public. *Nature Nanotechnology* 2(12): 732-734.

Segal, Marcia Texler and Theresa Martinez, eds. 2007. *Intersections of Gender, Race, and Class: Readings for a Changing Landscape*. Los Angeles: Roxbury Publishing.

Siegrist, Michael, Carmen Keller, Hans Kastenzholz, Sylvia Frey and Arnim Wiek. 2007. Laypeople's and experts' perception of nanotechnology hazards. *Risk Analysis* 27: 59-69.

Siegrist, Michael, Nathalie Staempfli and Hans Kastenzholz. 2008. Perceived risks and perceived benefits of different nanotechnology foods and nanotechnology food packaging. *Appetite* 51(2): 283-290.

Sims-Bainbridge, William. 2002. Public attitudes towards nanotechnology. *Journal of Nanoparticle Research* 4: 561-570.

Slovic, Paul. 2000. *The Perception of Risk*. London: Earthscan.

Stern, P.C. and Fineberg, V. 1996. *Understanding Risk: Informing Decisions in a Democratic Society*. National Research Council, Committee on Risk Characterization. Washington DC: National Academy Press.

Sturgis, Patrick and Nick Allum. 2004. Science in society: Re-evaluating the deficit model of public attitudes. *Public Understanding of Science* 13:55-74.

Sunstein, Cass R. 2002. The law of group polarization. *Journal of Political Philosophy* 10(2): 175.

Taylor, Verta. 1998. Feminist methodology in social movements research. *Qualitative Sociology* 21(4): 357-379.

Toumey, Christopher. 2006. Science and democracy. *Nature Nanotechnology* 1: 6-7.

Toumey, C. and D. Baird (2006). "Building nanoliteracy in the university and beyond." Nature Biotechnology 24(6): 721-722.

Wajcman, Judy. 1991. *Feminism Confronts Technology*. University Park, Pa: Pennsylvania State Univ Press.

Weaver, David, and Bruce Bimber. 2008. Finding News Stories: A Comparison of Searches Using LexisNexis and Google News. *Journalism and Mass Communication Quarterly* 83 (3):515- 530.

Weaver, David, Erica Lively, and Bruce Bimber. 2009. Searching for a frame: Media tell the story of technological progress, risk, and regulation in the case of nanotechnology. Forthcoming, *Science Communication*.

Wilkinson, Sue. 1999. Focus groups: A feminist method. *Innovations in Feminist Psychological Research*, eds. Ellen Kimmel and Mary Crawford, pp. 219-242. New York: Cambridge Univ. Press for American Psychological Association.

Wilsdon, J. 2005. *Small talk: New ways of democratising science and technology*. http://www.opendemocracy.net/globalization-accountability/science_2871.jsp (2-5-08)

Wilsdon, James and Rebecca Willis. 2004. *See Through Science: Why Public Engagement Needs to Move Upstream*. 2004-09-01. London: Demos.

Wynne, Brian, James Wilsdon and Jack Stilgoe, (2005), *The Public Value of Science*, London: Demos. Copy pdf available at [Demos website](#).

Risk Regulation

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Introduction

The use of engineered nanoparticles in sunscreen products offers an early and prominent consumer application of nanotechnology. Because such particles display chemical reactivity and other properties that are distinct from their macroscale counterparts, they are capable of constituting “effective broad-spectrum ultraviolet radiation (UVR) blocking agents with enhanced cosmetic transparency” (Faunce 2009). Translation: When sunblocking agents are reduced to the nanoscale, consumers can obtain the skin protection benefits of traditional sunscreens without the traditional unsightly white nose of a lifeguard. But might these unique nanoscale properties also raise health and safety concerns in addition to their cosmetic advantages?

In fact, nanoparticles such as titanium dioxide (TiO₂) have been shown to damage DNA when incorporated into human cells in vitro and exposed to ultraviolet-A light (Faunce 2009). Some, but not all, manufacturers of commercial sunscreens using TiO₂ and other nanoparticles apply a coating to the particles in order to reduce the chance of such harmful bioactivity. Even with this protective coating, however, the full long-term health effects of nanoparticles in sunscreens will only become clear *after* they have been used widely over a substantial period of time, given the novel properties that such agents display. Environmental effects of nanoparticles in sunscreens also will prove difficult to predict. For instance, emerging evidence suggests that TiO₂ and other nanoparticles commonly used in sunscreens may prove surprisingly disruptive of important biological roles played by bacterial microbes in the environment (Cimitile 2009). Once dispersed widely throughout aquatic and other ecosystems, engineered nanoparticles may produce a multitude of such unexpected and potentially harmful consequences.

Uncertainty and complexity of this sort lie at the heart of the risk regulation conundrum: Officials with responsibility for protecting the environment and human health and safety typically must make decisions regarding the permissibility of potentially harmful substances and activities well *before* the information and understanding necessary to make those decisions is actually available. Moreover, simply “erring on the side of safety” will not provide an adequate heuristic to guide officials through this epistemic void, given that a threat of harm often exists regardless of what course of conduct officials decide to adopt. In the context of nanoparticle-containing sunscreens, for instance, the cosmetic benefits of such products might make consumers more likely to use sunscreen products, thereby lowering their risk of skin cancer. On the other hand, the novel substances contained within such sunscreens also might turn out to have unintended and unanticipated adverse side effects. Responsible agency officials therefore find themselves in a tragic context of “risk versus risk” decision-making (Graham and Wiener 1995). That is, environmental, health, and safety impacts appear to be threatened irrespective of how the officials act.

How should regulators go about making such tragic choices? Should they seek regulations that are “comprehensively rational” (Diver 1981), that is, regulations that have been developed by fitting available empirical data regarding policy consequences into a formal decision rubric that attempts to generate an “optimal” outcome according to chosen value criteria? Or should they set and implement policies through a less theoretically ambitious, more pragmatic process of

goal identification, means selection, and periodic monitoring and adjustment – what has been famously called “the science of muddling through” (Lindblom 1959)? The first approach – which might be referred to as synoptic or rationalist – receives its most prominent practical application in the form of cost-benefit analysis. When conducting cost-benefit analysis, regulators evaluate proposed rules or policies by estimating their expected positive and negative effects, and by converting those effects into a common metric such as dollar equivalents. Once transformed in this manner, the consequences of the proposed regulation are then summed up in order to determine whether the regulation is socially desirable on net. Consistent with liberalism’s preference for a sphere of private activity relatively unimpeded by government oversight or intervention, proponents of cost-benefit analysis typically argue that regulations should be prohibited – or at least strongly disfavored – unless officials can show that a regulation would lead to a net improvement of overall social welfare (Charnley and Elliott 2002).

The second approach to risk regulation – which might be called incrementalist or pragmatic – eschews this brand of formal optimization in favor of simpler substantive principles and a stronger emphasis on procedural aspects of decision-making such as transparency, inclusiveness, and flexibility. The much-debated precautionary principle, for instance, seeks to trigger a process of public scrutiny and regulation through the bare admonition, “When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically” (Kysar 2006, quoting the Wingspread Declaration). Under this approach, regulators are to adopt measures that are proportionate to the threat perceived and that are open to revision as knowledge develops, but they are not to be hampered by a default assumption against government regulation prior to development of an adequate scientific demonstration of harm and an economic demonstration of the overall cost-benefit desirability of regulation. Pragmatic concepts such as the precautionary principle, sustainable development, or adaptive management often appear vague when compared to the formal outcome-based rationality of cost-benefit analysis (Marchant and Sylvester 2006). To some extent, this appearance arises simply because these concepts attempt to confront head-on the challenges presented by scientific uncertainty, ecological complexity, and social interrelation, rather than exclude or truncate those challenges as cost-benefit analysts tend to do in order to maintain the formal coherence of their framework. Moreover, some theorists would argue that concepts such as sustainability or the precautionary principle must be understood as motivated by much broader political concerns than the mere need for decision-making aids. In fact, some openly contend that “[n]either concept has much coherence other than is captured by the spirit that is challenging the authority of science, the hegemony of cost-benefit analysis, the powerlessness of the victims of environmental abuse, and the unimplemented ethics of intrinsic natural rights and intergenerational equity. It is because the mood of the times needs an organizing idea that the precautionary principle is getting attention” (Jordan and O’Riordan 1999, at p. 16).

The contrast between these policymaking paradigms is an old one, as is the debate surrounding their comparative advantages. As a philosophical matter, the topic was more or less conclusively surveyed in an article by Laurence Tribe that is now nearly four decades old (Tribe 1972). Nevertheless, the issues have been given new life in recent years, thanks to the emergence of contentious policy disputes involving climate change, genetically modified agriculture, synthetic biology, and similar high-profile subjects of risk regulation. These controversies bring to the fore a host of intellectual, moral, and political challenges: How can the democratic ideal of popular self-governance be reconciled with the increasingly technical and scientifically complex nature of environmental, health, and safety issues? To what extent can the norms, institutions, and procedures of science be relied upon to generate neutral and effective guidance to public policymakers? Have the actions of the tobacco industry, the fossil

fuel industry, the tort plaintiffs' bar, and other actors with a vested interest in the politicization of science irreparably damaged public confidence in the idea of "neutral" expertise? Even assuming that reliable and complete scientific knowledge could be obtained regarding the environmental, health, and safety effects of some substance or activity, can the social meaning of those effects be adequately captured by converting them into dollar values for cost-benefit balancing? What procedures for valuation should be used in order to ensure moral and political acceptance by the community in whose name the cost-benefit exercise is being undertaken? How should climate instability, cumulative toxic loading, desertification, ocean acidification, and other long-term effects of human activity be evaluated? Should policy consequences that affect future generations be given the same weight as those that affect the present generation or are there valid reasons to discount them? What, if any, obligations do nations have to consider the extraterritorial effects of their activities and policies? Can the principle of global free trade be reconciled with the desire of each individual nation to establish its own environmental, health, and safety policies? Does the undeniable reality of global economic and environmental interdependence render the case for a globally integrated regulatory system similarly undeniable?

This contribution to the University of Washington Nanoethics Graduate Education Symposium provides an introductory overview of risk regulation. It does not attempt to answer the myriad challenging questions raised in the previous paragraph, but instead simply to outline selected concepts and controversies from the field of risk regulation. Readers interested in further discussion may consult the sources referenced throughout the essay, as well as several recent book-length treatments of risk regulation (Kysar, forthcoming; Revesz and Livermore 2009; Adler and Posner 2006; Ackerman and Heinzerling 2004; Sunstein 2004; Shapiro and Glicksman 2003).

Concepts

The field of nanoscale science and engineering offers a particularly valuable context for considering risk regulation given that the field is riddled with scientific uncertainty and complexity, and given that both the risks and benefits of nanotechnology are potentially titanic. The same features that make nanomaterials possibly revolutionary as industrial inputs – namely, the unique chemical, optical, physical, and other characteristics that emerge at the nanoscale – also likely make them unsuitable for safety testing with existing risk modeling and assessment techniques. Moreover, even assuming that conventional toxicity testing methods could adequately evaluate engineered nanomaterials, cavernous data gaps would remain: According to a 2009 study, if all currently existing nanomaterials were to be tested for toxicity, the effort would require between \$249 million and \$1.18 billion and would take up to 53 years at current levels of investment (Chatterjee 2009). The task of governing nanoscale research and development is further complicated by the atmosphere of rhetorical extremism that characterizes public discussion regarding nanotechnology. As one observer noted, “[a] clear-eyed evaluation of the risks and benefit of nanotechnology is complicated by a very complex science – pushing the envelope of materials science – and by a venture capitalist-like hype about the potential of nanotechnology” (Wilson 2006).

Scientists have not been innocent of this “venture capitalist-like hype”; to the contrary, their bullish voices have encouraged the decision by governments around the world to provide billions of dollars of public funding for nanoscale science and engineering research. At the other extreme, activist groups have claimed to foresee near-biblical levels of harm and destruction that might emerge from nanotechnology. Thus, in what amounts to a particularly stringent invocation of the precautionary principle, these groups have called for an outright ban on

releases or distribution of the fruits of nanoscale science and engineering until such materials have been proven to be safe (Mandel 2008). Ordinary citizens, for their part, seem unlikely to invest the time and effort necessary to adequately understand the risks and benefits of nanotechnology from a scientific perspective. Instead, research suggests that citizens likely will resort to shorthand cultural heuristics in order to form views on whether nanotechnology is desirable or should be regulated. For instance, they might uncritically endorse whatever view is held by a particular spokesperson on nanotechnology who they believe happens to share their ideological viewpoint; alternatively, they might form general impressions based on an intuitive assessment of whether a proposed application of nanotechnology reinforces or undermines their conception of a well-ordered world (Kahan et al. 2008a; Kahan et al. 2008b). Even bare information provision will not avoid the influence of cultural cognition, as individuals will interpret such information through the lens of their pre-existing cultural orientation (Kahan and Bramam 2006). In fact, the provision of balanced factual information regarding the risks and benefits of nanotechnology has been shown to polarize individuals along the lines of their preexisting cultural outlooks, rather than bring them closer to consensus (Kahan et al. 2007). Thus, in light of these stable – and perhaps unavoidable – aspects of human cognition, it is unlikely that popular debate regarding the future of nanotechnology will resemble the Enlightenment ideal of dispassionate reasoning toward shared conclusions. Instead, passion and partisanship will inevitably color the conversation (Kahan 2007).

Some academics believe that such a context demands some form of regulatory check, often referred to as *regulatory impact analysis*, in order to temper the potentially irrational or misinformed political demands of the public (Sunstein 2005). Such a check aims to verify that proposed regulations serve legitimate social goals rather than “public hysteria” (Kuran and Sunstein 1999). More generally, regulatory impact analysis offers a mechanism for evaluating and disciplining the vast bureaucracy of agencies and officials that implements environmental, health, and safety law. In brief, regulatory impact analysis promises a comprehensive and systematic assessment of the impacts that a proposed regulation will have in order to evaluate whether the regulation will achieve its stated objectives and, more broadly, to determine whether it constitutes desirable policy. Regulatory impact analysis traces its roots to “Inflation Impact Assessments” that were required by the Carter Administration in the United States beginning in 1978. The scope of regulatory impact analysis was broadened significantly during the Reagan Administration through an executive order that required formal cost-benefit analysis of significant regulations (Sinden 2004). With some minor changes during the Clinton Administration to emphasize non-quantified and distributive aspects of proposed regulations, the approach of the Reagan executive order has now been in place in the United States for almost three decades. Despite this continuity, regulatory impact analysis has proven extremely controversial and, as discussed below, President Obama has signaled a desire to reevaluate how it is conducted and used. Before addressing such controversies, however, a brief overview of concepts and terminology from the risk regulation field is in order.

The simplest and least controversial form of regulatory impact analysis is *cost-effectiveness analysis*, which rests on the intuitive idea that actors ordinarily should seek to achieve a given goal in the least costly manner possible. For instance, if one’s goal is to travel to A, and if both B and C offer equally comfortable and reliable transportation methods to reach A, then ordinarily the less expensive provider between B and C should be chosen. Similarly, in the context of environmental law, one might distinguish between a law’s espoused goal and the means selected to achieve that goal. Within U.S. air and water pollution law, for instance, the U.S. Congress often has required that firms limit pollution to the level that is achieved by the best available pollution control technology. The goal of the statute is thus clearly identified: Regulated entities are to lower their emissions to the standard attained by the best performing

technology. Such *technology-based standards* were originally adopted by Congress because they were thought to be more administratively feasible than alternative regulatory approaches. In most cases, the Environmental Protection Agency (EPA) easily can identify which available technology performs best and can verify that firms are complying with the standard set through that technology. More ambitious approaches – such as *health-based standards* that require the agency to identify a safe level of human exposure or *environmental quality standards* that require the agency to determine what level of pollution a site can tolerate before becoming ecologically compromised – were thought to be much more informationally demanding and scientifically complex to implement.

Under technology-based standards, firms usually are allowed to adopt alternative means of complying with the mandated pollution reduction level, so long as firms can prove to regulators that their chosen method is equally environmentally effective as the technology that was used to establish the pollution standard (Driesen 2005). In this manner, cost-effectiveness is encouraged because firms have strong incentives to identify and implement the least costly way of achieving the mandated standard. The approach also reflects a clear demarcation of decisional authority: the U.S. Congress determines the overall social goal of pollution minimization by mandating adoption of the standard achieved by the best available technology; regulatory agencies then become responsible for the largely technical judgment of identifying the performance standard that is attainable by the best available technology; and, finally, individual companies are left to marshal their own specific knowledge and innovative potential in order to achieve the mandatory performance standard in the cheapest manner possible. In this example, cost-effectiveness analysis is conducted in-house by regulated firms as they seek to determine the cheapest way of complying with the pollution control standard. In other instances, the regulatory agency itself might conduct cost-effectiveness analysis in order to choose how to implement a given policy goal. In either case, the key analytical feature of cost-effectiveness analysis is the attempt to identify the least costly way of attaining a given goal, without calling into question the social desirability of the goal itself.

In recent years, the term “cost-effectiveness analysis” has also come to stand for a more theoretically ambitious and politically controversial type of regulatory impact analysis, one that is associated with the use of *regulatory league tables*. Such tables seek to rank and evaluate environmental, health, and safety regulations according to their overall cost-effectiveness, where cost-effectiveness is defined as the dollar cost of the regulation per life saved or per life-year saved by the regulation (Tangs and Graham 1996; Tangs et al. 1995). The stated goal of regulatory league tables is to help policymakers and the public better understand the social “return on investment” that is provided by various regulations. From the perspective of economic theory, a rational society should devote its scarce resources to regulatory opportunities that provide the biggest lifesaving “bang for the buck.” In that manner, the overall number of lives saved by society’s collective risk regulation policies will be maximized. Armed with the results of regulatory league tables, commentators frequently argue that a reordering of public risk regulation priorities could result in the same overall number of lives saved for dramatically less cost or, alternatively, dramatically more lives saved for the same cost. Some commentators go further to argue that league tables could be used to implement a cost per life saved cutoff. For instance, empirical analyses of blue collar labor markets suggest that workers in higher risk occupations receive a “wage premium” on account of the enhanced risk (Kochi, Hubbell, and Kramer 2006; Viscusi and Aldy 2003). The amount of the premium and the level of enhanced risk together imply that the monetary value of a statistical life is on the order of \$7 million. Thus, assuming that society wished to utilize this number as a budgetary cutoff for its lifesaving expenditures – on the theory that citizens should only be required to pay for lifesaving through

public policies at the same price that they seem willing to pay in their private activities – then any regulation costing more than \$7 million per life saved would be rejected.

Some commentators would apply a cost per life saved cutoff that is not set at the amount typically used by agencies when conducting regulatory impact analysis. Instead, they would apply a higher amount derived from what is known as *health-health analysis* (Lutter, Morrall, and Viscusi 1999; Lutter and Morrall III 1993). Studies in the health-health literature purport to demonstrate a dollar amount of government expenditure that necessarily entails the statistical loss of a life, by virtue of its displacement of private expenditure. Proponents of health-health analysis cite evidence that finds a significant correlation between income and health, particularly as measured by longevity. In light of this correlation, supporters argue that any regulation will entail at least some adverse health consequences, so long as compliance with the regulation requires a reduction in private income. That is, since wealthier appears to be healthier, any government regulation that reduces wealth might therefore also be expected to reduce health. Of course, this argument depends on a great deal of faith that the observed correlation is in fact a causal relationship. Other empirical work suggests that causality might run in the other direction – i.e., that healthier is wealthier – or that both wealth and health might be importantly determined by other factors, such as education or job stability, that are often the very kinds of positive life conditions that regulation seeks to provide (Parker 2003).

Health-health analysis is related to *risk-risk analysis*, which similarly seeks to compile a comprehensive assessment of the risk-related impacts that a given regulation will cause (Wiener 2002; Graham and Wiener 1995). Starting with the premise that risks are often created as well as reduced by regulation, analysts seek to identify the overall profile of risk tradeoffs posed by environmental, health, and safety regulation. Risk tradeoffs take a variety of forms. Some safety regulations are said to cause unintended consequences that may, on net, increase risk: Mandatory seat belt laws supposedly lead individuals to drive faster, childproof safety caps lull parents into being less diligent about hiding medicines, operation of air pollution control technology increases greenhouse gas emissions associated with electricity production, and so on. Similarly, some regulations cause harm by delaying the adoption of a product or technology that might be beneficial to human health or the environment: Premarket safety testing deprives patients of access to potentially efficacious drugs, restrictions on genetically modified crops might cause more rainforest to be converted to agricultural land, prohibiting test releases of nanoparticles for ecological reasons might delay the development of agents that actually help remediate pollution, and so on. This problem of risk tradeoffs is thought to be especially acute in the context of emerging nanotechnologies, given that numerous potential applications of nanotechnology stand to improve environmental quality and human health protection (Walsh 2007). Adopting a “go slow” or precautionary approach therefore might delay or prevent the attainment of risk benefits, in addition to whatever risk reductions are achieved by the cautionary regulation.

In light of the apparent pervasiveness of risk tradeoffs, commentators advocate forms of regulatory impact analysis that aim to systematically predict the impacts of regulation and to compile them within a single decision-making framework. In this manner, society can reduce the chance that its regulations will be premised on an incomplete or inaccurate understanding of what their effects will be. As noted in the introduction, the most well-known and controversial example of such a comprehensive decision-making framework is *cost-benefit analysis*, which seeks to translate all expected consequences of policies into monetary equivalent values so that society can decide whether an environmental, health, and safety regulation is “worth” its costs. Because cost-benefit analysis reduces all regulatory impacts to a common currency such as dollars, the framework is actually much more conceptually ambitious than its proponents

frequently contend. Cost-benefit analysis is not simply a practical method for ensuring attention to the consequences of policies; it is also, and always, an implicit argument in favor of a particular vision of how society should govern itself and attach value to its goods and activities. This is true most obviously in the sense that some method for transforming the diverse impacts of regulation into a common currency must be developed. The choice of value metric is a fundamental one, as it works to determine how heavily various kinds of policy impacts will be weighted in the ensuing cost-benefit calculus. Commonly, analysts utilize *willingness-to-pay* valuation methodologies; that is, impacts of policies are valued according to the amount that individuals seem to be willing to pay to either produce or avoid those impacts. An alternative approach would be to ask how much money individuals would be willing to accept in order to allow a particular policy impact to occur. The difference between willingness-to-pay and *willingness-to-accept* valuations can be dramatic: In the former case, responses are limited by the actual amount of money that individuals have available with which to express their preferences; in the latter case, individuals are not similarly constrained.

Moreover, even controlling for the influence of budget constraints, psychological studies consistently show that “people appear to value a commodity that they own much more than an identical commodity that they do not own” (Rachlinski and Jourden 1998, at p. 1151). That is, valuations are affected not only by beliefs, preferences, budget constraints and wealth effects, as economists have long recognized, but also by more subtle psychological phenomena. Put crudely, we do not just own our possessions because we value them; we value them, in part, because they are our possessions. Cost-benefit analysis struggles to accommodate such subtleties in the cognitive experience of ownership. Admitting that valuations differ depending on whether individuals are or are not initially endowed with the item or status in question reveals that policy analysis cannot adequately proceed based on willingness-to-pay valuations alone. The willingness-to-pay approach privileges the existing distribution of rights and resources in society when in fact policymaking often is designed to call into question whether that existing distribution is a just and sustainable one.

In addition to reducing the diverse array of effects of government action to a single currency, cost-benefit analysis also requires some method of equating effects across time. Typically, analysts reduce future impacts to a present value through the use of a procedure known as *discounting* (Kysar 2007). In a process that is essentially the inverse of compound interest, discounting identifies the amount of money in present value terms that would equal a future cost or benefit, assuming that the sum grows at a given percentage rate per year. The rate chosen for discounting in policy analysis is intended to reflect the *pure rate of time preference*, which is individuals’ preference for present over future consumption, and the *per-capita growth rate of well-being*, which depends on the rate of increase in consumption and the marginal utility provided by such increased consumption. The first factor is thought to be justified because cost-benefit analysis typically aims to reflect individuals’ preferences in its valuations. Thus, if it turns out that individuals prefer to consume goods now and delay bad experiences until later, then cost-benefit proponents believe that regulators should replicate that temporal impatience within policymaking – even if it occurs across multiple generations of humans, rather than within a single human life. The second factor is thought to be justified because it ensures that impacts are normalized according to how much they will improve or impair the well-being of the individuals actually affected. Generally speaking, the same outcome will have a greater relative impact on someone with lower well-being than someone with higher well-being. Stated more plainly, cost-benefit analysts discount future impacts of policies because people in the future are expected to be richer than people today. Oddly, cost-benefit analysts rarely adjust impacts in this fashion among members of the present generation; that is, for current policy consequences,

valuations are not adjusted based upon whether they are expected to befall rich or poor individuals.

Analysts sometimes justify discounting from an alternative perspective focused on the *opportunity costs* of policies. For instance, analysts often discount future impacts according to the rate of return available in private capital markets. The notion here is that society should only expend public resources to create future benefits if the implicit rate of return from such expenditures will be at least as good as the rate that could be achieved through alternative investments. In theory, even future generations will be “better off” from having their interests discounted in this way, since the eventual stock of resources bequeathed to them will have taken advantage of the best available investment opportunities, rather than having been devoted to the provision of specific goods and resources that may or may not turn out to be what future generations need. Much disagreement exists regarding the proper discount rate to utilize for these purposes. In contrast to the use of the rate of return from private capital markets, many analysts contend that a lower figure – such as the rate on long-term Treasury bills – should be used, given that many policies involve investment amounts or regulatory goals that could not realistically be substituted for by private investments. Still others contend that discounting for opportunity cost reasons is inappropriate in the context of major policy decisions such as climate change regulation, given that the outcome of the policy decision will itself substantially influence the private and public interest rates that supposedly provide the measure of the policy’s opportunity costs (Kysar 2007). As discussed in the next section, the role of discounting in cost-benefit analyses of long-term policy choices remains extremely controversial.

Controversies

In one of his earliest official acts, President Barack Obama issued a memorandum to the heads of executive departments and agencies expressing an intention to study and revise the manner in which the Office of Information and Regulatory Affairs (OIRA) within the U.S. Office of Management and Budget (OMB) conducts regulatory impact review, including cost-benefit analysis of proposed rules. He wrote:

The fundamental principles and structures governing contemporary regulatory review were set out in Executive Order 12866 of September 30, 1993. A great deal has been learned since that time. Far more is now known about regulation – not only about when it is justified, but also about what works and what does not. Far more is also known about the uses of a variety of regulatory tools such as warnings, disclosure requirements, public education, and economic incentives. Years of experience have also provided lessons about how to improve the process of regulatory review. In this time of fundamental transformation, that process – and the principles governing regulation in general – should be revisited.

I therefore direct the Director of OMB, in consultation with representatives of regulatory agencies, as appropriate, to produce within 100 days a set of recommendations for a new Executive Order on Federal regulatory review. Among other things, the recommendations should offer suggestions for the relationship between OIRA and the agencies; provide guidance on disclosure

* President Obama refers here to a revised version of the Reagan executive order on cost-benefit analysis that was adopted by the Clinton Administration.

and transparency; encourage public participation in agency regulatory processes; offer suggestions on the role of cost-benefit analysis; address the role of distributional considerations, fairness, and concern for the interests of future generations; identify methods of ensuring that regulatory review does not produce undue delay; clarify the role of the behavioral sciences in formulating regulatory policy; and identify the best tools for achieving public goals through the regulatory process.

At the time of this writing, the results of the Obama Administration's reevaluation of regulatory impact analysis were not yet known. The call for recommendations, however, does provide something of a roadmap to the controversies that have surrounded regulatory impact analysis.

First, President Obama's query regarding "the relationship between OIRA and the agencies" and "the role of cost-benefit analysis" seems to address what many have regarded as the inappropriate expansion of the OMB and OIRA's role in agency affairs. To many observers, cost-benefit analysis and other tools of regulatory review are best understood, not as abstract decision-making techniques, but as techniques promoted and deployed in specific political institutional contexts. In the United States, for instance, formal regulatory analysis of any stripe cannot be separated from the history of presidential power that such analysis has helped to consolidate. No matter which political party occupies the White House, formal regulatory analysis of agency action helps to ensure that the President maintains a strong grip over the goals and accomplishments of the EPA, the Occupational Health and Safety Administration, and other agencies charged with protecting public health and the environment. In fact, the stated rationale behind regulatory league tables – i.e., that they help enable allocation of scarce public resources to the most cost-effective lifesaving opportunities available – seems to presume an all-powerful executive capable of shifting budgets and targeting investments across the full range of ways in which government might seek to enhance well-being. In actuality, however, agencies cannot range in this way nor would we necessarily want them to: Agencies are limited entities created and tasked by Congress to accomplish specific goals. They are the agents of a legislative body which itself is the agent of "We the People." To many observers, then, the impetus behind league tables and related regulatory reform efforts seems to be a desire to cut Congress and its constituencies out of the national conversation on how best to achieve a just, sustainable, and prosperous society.

Second, President Obama's emphasis on the importance of "disclosure and transparency" and the need to "encourage public participation in agency regulatory processes" resonates with criticisms both of OIRA in particular and of cost-benefit analysis in general. Critics contend that the OIRA review process has often been undertaken without the level of public disclosure and involvement required of agency rulemaking under the Administrative Procedure Act. Yet agencies often are forced to revise dramatically their policy implementation efforts in light of the actual or anticipated results of the OIRA cost-benefit review. Thus, the regulatory impact analysis process, which nominally is supposed to act as an *ex post* check on agency decision-making, instead becomes an *ex ante* driver of the content of new regulations. As a result, critics contend, the public is cut out of important aspects of the policy implementation process through informal consultations between agencies and OIRA, and the legislative goals established by Congress are aggressively redefined through the influence of cost-benefit analysis, even for statutes in which cost-benefit analysis was considered and rejected by Congress as a standard for determining appropriate levels of protection (Kysar 2009a).

More broadly, many observers of the regulatory state believe that cost-benefit analysis serves to undermine public engagement with the policymaking process by transforming important moral

and political issues into a highly technical and opaque exercise. Supporting documentation for a cost-benefit analysis of major EPA rules may consist of hundreds of pages of scientific risk assessments, experimental economic valuation studies, academic literature reviews, and other specialized documents. Throughout these pages will be countless moments in which analysts make debatable assumptions or inferences. In one recent EPA rulemaking, for instance, analysts quantified and monetized the health benefits of mercury emissions reduction by estimating the number of intelligence quotient (IQ) points that are lost from in utero mercury exposure, which the analysts transformed into dollar values by referencing empirical studies of the relationship between IQ levels and earning potential. Citing a need to be comprehensive, however, the analysts then reduced the dollar value of avoided IQ losses due to the fewer years of education that individuals with lower IQ levels typically seek (which, in turn, “saves” society the resources that would be lost through tuition expenditures and foregone years of productive labor). Thus, the benefit of avoiding mercury-induced mental impairment of children was first reduced to a simple function of the wage impact of intelligence and then further reduced to reflect the offsetting “costs” associated with higher IQ levels (O’Neill 2007; O’Neill 2004). Obviously a host of moral and political issues are being implicitly resolved through this supposedly objective and technical exercise, yet the ordinary citizen has little opportunity even to recognize that such resolutions are occurring.

This inaccessibility of cost-benefit analysis is related to a larger problem of harmonizing technical expertise with democratic legitimacy in the modern regulatory state (Bucchi and Neresini 2008; Coglianese and Marchant 2004; Latour 2004; Kleinman 1998; Cozzens and Woodhouse 1995; Ezrahi 1990; Jasanoff 1990; Collingridge and Reeve 1986; Dewey 1927). Environmental, health, and safety regulation undeniably requires expertise, yet it ultimately must be comprehensible to the public in order to ensure its democratic bona fides. An increasingly important strand of scholarly literature therefore focuses on the role of scientific information and expertise as *itself* something to be regulated and managed for the public benefit (Karkkainen 2006; Jasanoff 2003; Pestre 2003; Gibbons et al. 1994; Funtowicz and Ravetz 1993; Funtowicz and Ravetz 1992; Wynne 1992; Ravetz 1987). One particularly prominent understanding of the precautionary principle, for instance, is as a device to alter the regulatory burden of proof such that regulators need not demonstrate the same level of clarity and predictability of harm in order to justify government intervention into markets or other spheres of private activity. Instead, once regulators have met some threshold showing of potential harm from a proposed activity, substance, or technology, then the burden of proof shifts onto the promoter of that potentially harmful act to demonstrate that it is safe after all. Although in part defended on fairness grounds, this shifting of the burden of proof also can be defended as a means of fostering quicker and deeper understanding of the risks and benefits of novel technologies and activities. The precautionary principle in this sense seeks to marshal the in-house research capabilities of firms on behalf of the public’s desire for greater understanding of the environmental, health, and safety threats it may face in the future (Kysar 2009b). Cost-benefit analysis, in contrast, tends to treat the development of scientific information and understanding as something that happens outside of the framework of policymaking. Requisite data for risk assessment and cost-benefit estimation are simply expected to arrive somehow such that the regulatory impact analysis mandate can be easily satisfied by agency officials.

Third, the call to “identify methods of ensuring that regulatory review does not produce undue delay” appears to respond to the long-standing complaint of scholars and activists that regulatory impact analysis leads to a situation of “paralysis by analysis” (McGarity 1998). The sheer informational and analytical demands of cost-benefit analysis and related forms of regulatory review are said to consume vast amounts of time and divert agency resources away from the implementation of statutory programs. This problem is said to be particularly acute at

agencies such as the EPA, where the backlog of unimplemented programs and unaddressed problems is enormous. Thus, critics argue that regulatory impact analysis – which is designed in part to ensure that agencies attend to the opportunity costs of proposed rules – poses opportunity costs *itself*, given the limited time, personnel, and budget available to agencies as they seek to fulfill their statutory missions. The failure to consider these opportunity costs of regulatory impact analysis is consistent with an overall focus on the outcome optimality of regulations as a *substantive* matter, as opposed to the legitimacy and practicality of regulations' adoption and implementation as a *procedural* matter.

Finally, as suggested in the previous section, “the role of distributional considerations, fairness, and concern for the interests of future generations” is a particularly vexed one for regulatory impact analysis. Within cost-benefit analysis, for instance, the choice of willingness-to-pay as a basic valuation metric serves to powerfully reinforce the status quo distribution of wealth and resources in society; similarly, the decision to discount future values at some nontrivial rate indirectly resolves questions of intergenerational justice in a way that is at best debatable. These two fundamental decisions – of what metric to deploy for valuing policy impacts and of how to handle the temporal dimension of policymaking – are unavoidably moral and political in nature, yet proponents of cost-benefit analysis try mightily to present their methodology as neutral and objective (Kysar 2009a). The promise of such comprehensive rationality is deeply appealing. Scientific knowledge is frustratingly incomplete, direct value conflicts are uncomfortable, and political compromise is unseemly – thus, the prospect of rising above the mud through a type of formal, constrained decision framework such as cost-benefit analysis seems attractive when compared to yet more “muddling through.” But as the controversies reviewed in this section suggest, cost-benefit analysis does not actually avoid the mud and muddle of politics, nor is it devoid of debatable moral content. Instead, it utilizes a host of debatable assumptions and exclusions in order to produce only an appearance of objectivity.

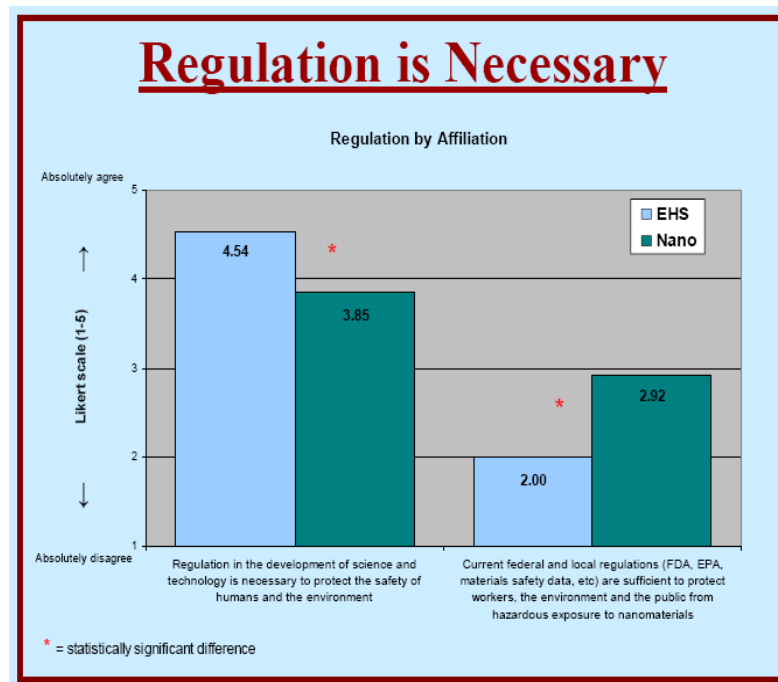
Conclusion

Apart from their support of public research funding, scientists and engineers often seem reluctant to engage with the broader policy issues that are raised by their work and its downstream impacts. Nanoscale scientists and engineers provide no exception: In a study undertaken at the University of Washington, faculty members associated either with the Center for Nanotechnology or the Department of Occupational Health Sciences were surveyed with respect to their knowledge and views regarding nanotechnology and the need for regulation (Hughes et al. 2007). As with many other such surveys, neither faculty group reported being likely to discuss the social and ethical implications of nanotechnology or to discuss exposure hazards. Both groups of faculty members reported a lack of trust in government regulatory agencies to minimize the risks of scientific development, and both groups tended not to trust business leaders within the nanotechnology industry to minimize risks associated with nanotechnology development. Further, both groups agreed that “regulation is necessary to protect the safety of humans and the environment,” although the occupational health researchers were more likely to do so than the nanotechnology researchers. Likewise, both groups disagreed that the current regulatory framework is sufficient to protect workers, the environment, and the public from hazardous exposures to nanomaterials (see Figure 1).

Thus, a picture emerges from this study of science faculty who believe that regulation is necessary and that the current set of laws and regulations is inadequate, and yet who also trust neither business nor the government to improve matters. Moreover, the scientists themselves are not talking to their colleagues or others about environmental, health, and safety issues. When these faculty were asked whether the precautionary principle is an appropriate regulatory

strategy for handling nanomaterials, an even cloudier picture appears (see Figure 2). For both groups combined, majority support for the precautionary principle was found – an interesting finding given that the actual regulatory approach currently taken in the United States with respect to nanotechnology would not be considered precautionary. Furthermore, a startling percentage of respondents stated that they “don’t know” whether the precautionary principle is an appropriate principle for handling hazards associated with nanotechnology development. That is, even though the survey respondents were first read a brief description of the precautionary principle, nearly half of the nanoscientists and nanoengineers still claimed not to have an opinion on whether it is an appropriate regulatory strategy for nanotechnology. Such reluctance to espouse a view on the regulatory oversight of nanotechnology by some of the very few people in the country who actually understand technical aspects of nanoscience is worrisome. These are precisely the individuals that society needs to have intellectually and emotionally engaged with the broader implications of nanotechnology developments, acting not only as citizens who take their democratic role seriously, but as citizen-scientists who see their training and expertise as carrying a responsibility to help raise the level of society’s political discourse concerning science and technology. Whether or not the ethical responsibilities of scientists extend beyond the laboratory to the downstream uses and misuses of their discoveries is a complicated question about which a range of reasonable views exists. Some believe that science functions best when researchers are allowed to focus single-mindedly on discovery, rather than being asked to balance considerations of safety and justice as well. Others regard self-scrutiny and foresight on behalf of the public interest to be a basic moral duty attached to the scientific role. Separate and apart from this issue, however, is the question of how those with scientific training and expertise fulfill their duties as citizens within a democratic society. Becoming knowledgeable and concerned over public policy issues such as environmental, health, and safety risks of nanotechnology might be considered a service of citizenship that society demands from scientists and engineers in exchange for the position of relative influence and prestige that they are afforded.

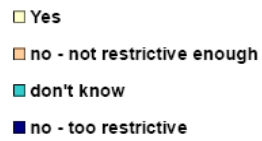
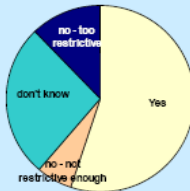
Figure 1



Precautionary Principle

The precautionary principle is an appropriate strategy for reducing hazards or risks associated with nano-development

Environmental Health Sciences
& Nanotechnology
COMBINED



Environmental Health
Scientists Only



Nanotechnologists
Only



Source: Hughes 2007.

References

- Ackerman, F. and L. Heinzerling. 2004. *Priceless: On Knowing the Price of Everything and the Value of Nothing*. New York: New Press.
- Adler, M. D. and E. A. Posner. 2006. *New Foundations of Cost-Benefit Analysis*. Cambridge, MA: Harvard University Press.
- Bucchi, M. and F. Neresini. 2008. Science and Public Participation. In *The Handbook of Science and Technology Studies*, eds. E. J. Hackett et al., 449-472. Cambridge, MA: The MIT Press.
- Charnley, G. and E. D. Elliott. 2002. Democratization of Risk Analysis. In *Human and Ecological Risk Assessment: Theory and Practice*, ed. Dennis J. Paustenbach, 1399-1414. New York: John Wiley and Sons, Inc.
- Chatterjee, R. 2009. Calculating the Costs of Nanohazard Testing. *Environmental Science and Technology* 43(10): 3405, DOI: 10.1021/es900758w.
- Cimitile, M. 2009. Nanoparticles from Sunscreens Damage Microbes. *Environmental Health News*. Available from URL: <http://www.environmentalhealthnews.org/ehs/news/nanoparticles-damage-microbes>.
- Coglianesi, C. and G. E. Marchant. 2004. Shifting Sands: The Limits of Science in Setting Risk Standards. *University of Pennsylvania Law Review* 152: 1258-1360.
- Collingridge, D. and C. Reeve. 1986. *Science Speaks to Power: The Role of Experts in Policy Making*. London: Frances Pinter (Publishers).
- Cozzens, S. E., and E. J. Woodhouse. 1995. Science, Government, and the Politics of Knowledge. In *Handbook of Science and Technology Studies*, eds. S. Jasanoff et al., 533-553. London: Sage.
- Dewey, J. 1927. *The Public and Its Problems*. New York: Holt.
- Diver, C. S. 1981. Policymaking Paradigms in Administrative Law. *Harvard Law Review* 95: 393-434.
- Driesen, D. 2003. Distributing The Costs Of Environmental, Health, And Safety Protection: The Feasibility Principle, Cost-Benefit Analysis, And Regulatory Reform. *Boston College Environmental Affairs Law Review* 32: 1-95.
- Ezrahi, Y. 1990. *The Descent of Icarus: Science and the Transformation of Contemporary Democracy*. Cambridge, MA: Harvard University Press.
- Faunce, T. A. 2009. Safety of Nanoparticles in Sunscreens. *Medical Journal of Australia* 190(8): 463-463.
- Funtowicz, S. O. and J. R. Ravetz. 1992. Three Types of Risk Assessment and the Emergence of Post Normal Science. In *Social Theories of Risk*, eds. S. Krimsky and D. Goldring, 251-283. New York: Praeger.

Funtowicz, S. O. and J. R. Ravetz. 1993. Science for the Post-normal Age. *Futures* 25(7): 739-55.

Gibbons, M. et al. 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. London: Sage.

Graham, J. D. and J. B. Wiener. 1995. *Risk Versus Risk: Tradeoffs in Protecting Health and the Environment*. Cambridge, MA: Harvard University Press.

Heinzerling, L. 2002. Five-Hundred Live-Saving Interventions and their Misuse in the Debate Over Regulatory Reform. *Risk: Health, Safety and Environment* 13: 151-175.

C. Hughes et al. 2007. *Perceived Risks and Hazards of Nanotechnology*. Unpublished Master's Thesis. Seattle, Washington: University of Washington.

Jasanoff, S. 1990. *The Fifth Branch: Science Advisers as Policymakers*. Cambridge, MA: Harvard University Press.

Jasanoff, S. 2003. Technologies of Humility: Citizen Participation in Governing Science. *Minerva* 41: 223-244.

Jordan, A. and T. O'Riordan. 1999. The Precautionary Principle in Contemporary Environmental Policy and Politics. In *Protecting Public Health And The Environment: Implementing The Precautionary Principle*, eds. C. Raffensberger and J. Tickner, 15-35. Washington, D.C.: Island Press.

Kahan, D. M. 2008. Two Conceptions of Emotion in Risk Regulation. *University of Pennsylvania Law Review* 156: 741-766.

Kahan, D. M. et al. 2007. Culture and Identity-Protective Cognition: Explaining the White-Male Effect in Risk Perception. *Journal of Empirical Legal Studies* 4(3): 465-505.

Kahan, D. 2007. The Cognitively Illiberal State. *Stanford Law Review* 60: 115-154.

Kahan, D. & D. Braman. 2006. Cultural Cognition and Public Policy. *Yale Law and Policy Review* 24: 147-170.

Kahan, D et al. 2007. Affect, Values, and Nanotechnology Risk Perceptions: An Experimental Investigation. Available from URL: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=968652.

Kahan, D. M. et al. 2008a. The Future of Nanotechnology Risk Perceptions: An Experimental Investigation of Two Hypotheses. Available from URL: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1089230.

Kahan, D. et al. 2008b. Biased Assimilation, Polarization, and Cultural Credibility: An Experimental Study of Nanotechnology Risk Perceptions. Available from URL: http://www.nanotechproject.org/process/files/5960/brief2kahan_final.pdf.

Karkkainen, B. C. 2006. Information-Forcing Environmental Regulation. *Florida State University Law Review* 33: 861-902.

- Kleinman, D. K. 1998. Beyond the Science Wars: Contemplating the Democratization of Science. *Politics and the Life Sciences* 16(2): 133-145.
- Kochi, I., B. Hubbell, and R. Kramer. 2006. An Empirical Bayes Approach to Combining and Comparing Estimates of the Value of a Statistical Life for Environmental Policy Analysis. *Environmental and Resource Economics* 34: 385-406.
- Kuran T, & C. R. Sunstein. 1999. Availability Cascades and Risk Regulation. *Stanford Law Review* 51: 683–768.
- Kysar, D. A. Forthcoming. *Regulating from Nowhere: Environmental Law and the Search for Objectivity*. New Haven: Yale University Press.
- Kysar, D. A. 2009a. Fish Tales. In *Alternative Approaches to Regulatory Impact Analysis: A Dialogue Between Advocates and Skeptics of Cost-Benefit Analysis*, eds. W. Harrington, L. Heinzerling, and R. Morgenstern. Washington, D.C.: Resources for the Future.
- Kysar, D. A. 2009b. Ecologic: Nanotechnology, Assurance Bonding, And Symmetric Humility. *UCLA Journal of Environmental Law and Policy* 27(2):__-__.
- Kysar, D. A. 2007. Discounting . . . On Stilts. *University of Chicago Law Review* 74: 119-138.
- Kysar, D. A. 2006. It Might Have Been: Risk, Precaution, and Opportunity Costs. *Journal of Land Use and Environmental Law* 22: 1-57.
- Latour, B. 2004. *Politics of Nature: How to Bring the Sciences Into Democracy*. Cambridge, MA: Harvard University Press.
- Lindblom, C. 1959. The Science of “Muddling Through.” *Public Administrative Review* 19(2): 79-88.
- Lutter, R., J. Morrall, and W. K. Viscusi. 1999. The Cost-Per-Life-Saved Cutoff for Safety-Enhancing Regulations. *Economic Inquiry* 37: 599-608.
- Lutter, R. and J. F. Morrall III. 1993. Health-Health Analysis: A New Way to Evaluate Health and Safety Regulation. *Journal of Risk and Uncertainty* 8(1): 43-66.
- Mandel, G. 2008. Nanotechnology Governance. *Alabama Law Review* 59: 1323-1384.
- Marchant, G. E. and D. J. Sylvester. 2006. Transnational Models for Regulation of Nanotechnology. *Journal of Law, Medicine and Ethics* 34(4): 714-725.
- McGarity, T. O. 1998. A Cost-Benefit State. *Administrative Law Review* 50: 7-79.
- O’Neill, C. A. 2004. Mercury, Risk, and Justice. *Environmental Law Reporter* 34: 11070-11115.
- O’Neill, C. A. 2007. Protecting the Tribal Harvest: The Right to Catch and Consume Fish. *Journal of Environmental Law and Litigation* 22: 131-151.
- Parker, R. W. 2003. Grading the Government. *University of Chicago Law Review* 70: 1345-1485.

Pestre, D. 2003. Regimes of Knowledge Production in Society: Towards a Moral Political and Social Reading. *Minerva* 41: 245-261.

Rachlinski, J. J. and F. Jourden. 1998. Remedies and the Psychology of Ownership. *Vanderbilt Law Review* 51: 1541-1582.

Ravetz, J.R. 1987. Uncertainty, Ignorance, and Policy. In *Science for Public Policy*, eds. H. Brooks and C. Cogsei, 77-95. New York: Pergamon Press.

Revesz, R. and M. Livermore. 2008. *Retaking Rationality: How Cost-Benefit Analysis Can Better Protect the Environment and Our Health*. Oxford: Oxford University Press.

Sinden, A. 2004. Cass Sunstein's Cost-Benefit Lite: Economics for Liberals. *Columbia Journal of Environmental Law* 29: 191-241.

Shapiro, S. A. and R. L. Glicksman. 2003. *Risk Regulation At Risk: Restoring A Pragmatic Approach*. Palo Alto: Stanford University Press.

Sunstein, C. R. 2004. *Risk and Reason: Safety, Law, and the Environment*. Cambridge: Cambridge University Press.

Sunstein, C. R. 2005. *The Laws of Fear*. Cambridge: Cambridge University Press.

Tangs, T. O. and J. D. Graham. 1996. The Opportunity Costs of Haphazard Social Investments in Life-Saving. In *Risks, Costs, And Lives Saved: Getting Better Results From Regulation* 167, ed. R. W. Hahn.

Tangs, T. et al. 1995. Five-Hundred Life-Saving Interventions and Their Cost-Effectiveness. *Risk Analysis* 15: 369-390.

Tribe, L. H. 1972. Policy Science: Analysis or Ideology? *Philosophy and Public Affairs* 2: 66-110.

Viscusi, W. K. and J. E. Aldy. 1993. The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World. *Journal of Risk and Uncertainty* 27(1): 5-76.

Walsh, B. 2007. Environmentally Beneficial Nanotechnologies: Barriers and Opportunities.

Wiener, J. B. 2002. Precaution in a Multi-Risk World. In *Human And Ecological Risk Assessment: Theory And Practice*, ed. D. D. Paustenbach, 1509-1531.

Wilson, R. F. 2006. Nanotechnology: The Challenge of Regulating Known Unknowns. *Journal of Law, Medicine, and Ethics* Winter: 704-713.

Wynne, B. 1992. Uncertainty and Environmental Learning: Reconceiving Science and Policy in the Preventive Paradigm. *Global Environmental Change* June: 111-27.

Teaching Nanoethics to Graduate Students

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Background/Rationale

In the decade since the University of Washington (UW) launched the nation's first doctoral program in nanotechnology,ⁱ doctoral training in the scientific and technical aspects of this newly established field has become widespread. As increased research and the growing nanotechnology enterprise has brought many promises of nanotechnology into reality, we recognized that students in UW's nanotechnology Ph.D. program need more than just technical training to be responsible practitioners – they also require parallel training in the societal and ethical implications of these unprecedented technological developments. Providing such training requires concerted effort in cross-disciplinary collaboration and communication, not just between scientists and engineers or between biological and physical scientists, which was necessary for their technical training, but among technologists, scientists, engineers, medical practitioners, social scientists and humanists. To address these issues, two interdisciplinary centers at the University of Washington, the Center for Nanotechnology (CNT) and the Center for Workforce Development (CWD), cooperated to offer an interdisciplinary Seminar in Nanoethics during winter quarter 2009, co-taught by a social scientist (Ph.D. Communication) and a practicing nanotechnology researcher (Ph.D. Physics). This paper details the historical background, syllabus, audience, and impact of this new course with an aim to aid others implementing similar courses.

Taking an interdisciplinary perspective, this seminar examined a broad range of ethical issues associated with nanotechnology. Topics included environmental, health, and safety concerns; security and privacy implications; economic effects; national and international political implications; media and public perceptions; cultural and religious repercussions; medical technologies; and legal and regulatory issues. Weekly guest speakers (from across the UW campus and outside) presented a particular aspect of ethical interest, discussed how it relates to nanotech research, and examined possible responses. Students worked in small groups to develop a short case study based on one of the topics presented. The case studies have been made available online through an NSF-funded website on nanoethics at the University of Washington.ⁱⁱ The course was offered for undergraduate or graduate credit and was open to students from across the UW campuses.

The new course was introduced to provide a needed focus on nanoethics in graduate education, particularly for graduate students who are preparing themselves for careers in nanoscale science and technology, whether as biologists, chemists, physicists, or engineers. The course was initially developed as part of the nanotechnology degree program, but, when offered, it also attracted non-scientists curious about applications of ethics to the emerging field of nanotechnology. Students in UW's interdisciplinary Dual Ph.D. Degree Program in Nanotechnology are admitted through one of ten participating departments in engineering,

medicine and the natural sciences. After completing both the requirements of their home department and additional interdisciplinary requirements, they receive a dual degree in “*Home-department* and Nanotechnology.” In addition to completing a nanotechnology-related thesis under the supervision of one of the 85 CNT faculty members, students must complete nanotechnology-related coursework and lab rotation outside their home department, attend our interdisciplinary colloquium series, and complete our core course “Frontiers in Nanotechnology.” Prior to the development of the Seminar in Nanoethics, the only exposure to scientific ethics and the societal impact of nanotechnology in the program was an occasional presentation in the nanotechnology seminar series and one or two class periods in the core course. Students enrolled in the Frontiers in Nanotechnology class between 2006 and 2009 (N=58) reported the most common mode of engagement with societal and ethical issues as occurring informally with colleagues (66%) rather than in the classroom (30%), although many (78%) indicated that they could imagine dealing with these issues in the future.

Ethnographic fieldwork at the University of Washingtonⁱⁱⁱ indicated that most graduate students involved in research at the nanoscale have not been exposed to discussions of ethical issues in their undergraduate or graduate studies. Consequently, they do not find these issues to be particularly relevant to their work as scientists. Notwithstanding, the following issues were raised by graduate students: implications of accepting funding from industry and government, unlabeled products on the market containing nanoparticles, how current regulatory agencies can keep up with a rapidly-developing technology such as nanotechnology, and pollution and natural resource depletion caused by the production of nanoelectronics. Despite the interest in these issues, the students appeared to be largely ill-equipped to integrate their concern about ethical issues into their careers. Reasons for this include a perception that ethics is not a scientist’s concern, that these issues are simply not addressed in their classes and coursework, and a reluctance to be seen as advocating for a moratorium on scientific inquiry. In short, these findings suggested a demonstrated interest in ethics among the scientific graduate community, but few resources available to them to integrate their concerns into their studies.

University of Washington Initial Response

In response to these findings, the CNT and CWD pursued several avenues to increase both awareness of societal and ethical issues in nanotechnology and the ability of our students to deal intelligently with them. We initially worked through existing venues, inviting at least one speaker each year for the Nanotechnology Seminar Series to speak specifically about ethics in nanotechnology, and encouraging all speakers in both the seminar series and the Frontiers in Nanotechnology (FN) class to address potential societal impacts of their research. We also changed first one, and later two class periods in the required FN class to discuss these issues. In developing these classes, we benefitted from case studies developed at the University of New Mexico as part of the National Nanotechnology Infrastructure Network, to which UW belongs. Kirsty Mills of UNM was invited to give a CNT Seminar (Feb 2006)^{iv} in which she presented several short case studies in nanoethics, and she worked with Professor Olmstead to choose and adapt some of her case studies for discussion in the FN class that April. We also used case studies developed for general scientific ethics at the National Academy of Sciences.^v In 2008, we replaced some of these with case studies developed at the Center for Nanotechnology in Society at Arizona State University.^{vi} Social scientists from the CWD also attended class for these discussions, giving students well-needed balance between technological and social points of view.

Students responded very well to the inclusion of ethical case study discussions in the FN class. In post-class surveys, no students in four years worth of classes checked “Not useful -- cut this out next year,” and fewer than 10% checked “OK, but time better spent elsewhere” for any of the several case studies used. The vast majority believed the discussions were directly useful in either their current or imagined future lives, with the remaining 8-35% believing the discussions related to each case study were “Worth class time, but not directly relevant to me.” The general scientific ethics discussions and case studies specific to nanotechnology were of comparable interest to the students.

We used two different approaches to structuring the classroom discussion: (a) presentation of several short (one power-point slide) scenarios, followed by a structured list of discussion questions that the entire class (14-20 students) discussed together; and (b) slightly more detailed scenarios (one typewritten page) discussed in small groups (4-6 students) with major discussion points then shared with the entire class (each group discussed a different scenario). The latter was more successful in bringing quiet students into the discussion and in allowing for depth on a particular topic, while the former brought a wider variety of topics to the attention of the entire class. We recommend breaking into smaller group discussions for a class larger than 12-15 students.

In the course of teaching these required class sessions on ethics in nanotechnology, we observed (a) many students desired to spend more time learning about these issues (over $\frac{3}{4}$ reported being “probably” or “definitely” interested in taking a seminar on nanoethics) and (b) very few resources were available for faculty to prepare for discussions that lie outside their traditional expertise. In particular, while several “power-point-level” case studies were available, few if any had enough detail and background information for a non-expert to teach effectively. To address these observations, CNT and CWD faculty wrote a successful proposal to the National Science Foundation to develop a class in which the students would both learn about societal and ethical issues related to nanotechnology and create materials to aid others in teaching classes that address these issues. The conference at which this paper is being presented (and its subsequent archival on the world-wide-web) is another aspect of this NSF-sponsored project, “Nanoethics on the World Wide Web: Helping Faculty Enhance Graduate Education.”^{vii}

Structure for Seminar in Nanoethics

Graduate students in nanotechnology tend not to want to take time from their research for “non-essentials,” and we knew that many of our students (and especially their advisors) were skeptical of the need for an entire course on nanoethics. We thus structured the class for minimal impact on students’ research: a 2-credit seminar, graded pass/fail, meeting at times unlikely to conflict with other seminars or data acquisition (9:30-10:20, Tuesday/Thursday, before most experiments get started). We also limited out-of-class commitment to 1-2 hours of pre-class reading per week, plus working in an interdisciplinary group to create a detailed case-study.

The class was co-taught by the authors, whose complementary backgrounds (communication and physics) played a significant role in enriching the class. Our respective professions as a physical scientist (MO) and social scientist (DB) allowed us to address the diverse aspects of the material covered in the class. For example, MO addressed questions about the science behind nanotechnology and DB provided information about the social processes that influence knowledge production. We also had complementary personal networks of appropriate guest presenters.

While the interdisciplinarity of the class was ideal from a pedagogical point of view, administratively, the class had no obvious departmental home or institutional support. The Seminar in Nanoethics was approved on a one-time basis as an undergraduate/graduate special topics class in the physics department (Phys 428/576), but there was reluctance to give graduate credit in physics for a class that had no specific physics prerequisite. Professor Olmstead also taught the class as an overload in addition to her regularly scheduled class, while Dr. Bassett was partially supported by the NSF grant mentioned above. These administrative issues are likely common to all universities, and call for changes at levels above departments or colleges. The CNT is currently working with the university to create a “NANO” prefix to consolidate all courses relevant to nanotechnology in the course catalog. Another long-term institutional need is a schema in which interdisciplinary classes are supported on an equal footing with more traditional classes centered in a single department.

Much of the material covered in this seminar was new to one or both of the instructors, but there was considerable expertise spread across campus. We thus chose a format that alternated presentations by experts with instructor-led discussions of both the previous class’ presentation and the readings (usually recommended by the speaker) for the following presentation. In general, we found that the 50 minute class period was not quite enough, especially on days with presentations; the 80 minute period of the FN class would be preferred. Fortunately, we met in a room that was empty both before and after class, so that interested students (and occasionally speakers) could remain for additional discussion, and student teams could meet in the classroom before or after class to discuss their case studies.

Students were expected to be active and prepared participants every day of class, with any assigned readings completed prior to each class meeting. Active participation in class discussions by all students showed this to be the case, and reflected their intrinsic interest in the material.

Topics and Syllabus

The topic of Ethics and Nanotechnology is wide-ranging, as evidenced by the diversity of topics discussed in this conference proceedings. Also, given the paucity of structured learning about general ethics or scientific conduct for most students of nanotechnology, or of nanoscale science and technology for most students of ethics, it was necessary to give background material in both areas.

Course objectives were to:

1. Identify and address ethical issues associated with nanotechnology.
2. Assess possible responses to the issues raised.
3. Develop case studies that provide additional direction for the topics raised and make available as online resource for graduate students and faculty.

The syllabus is given in Table I. The presenters included: practitioners of nanotechnology research, who spoke both on the impact of societal issues on their research and vice versa; researchers on ethics and its applications, who gave both an overview of ethical theory and examples of its application to medical genetics; both a social and physical scientist investigating the impact of technology on social structures; and social scientists who have studied the views of practicing nanotechnologists on ethical issues and the ways in which they communicate about these issues. We used the first two weeks for introductions to both ethics and nanotechnology with a combination of presentations and discussion. The student discussion

uncovered student expertise in science, engineering and humanities, as well as in policy, and laid important groundwork for respectful peer-to-peer education the remainder of the quarter. It is important to establish this rapport early in the quarter, with students being willing to express both knowledge and ignorance to each other. Dynamic speakers involving the entire class in discussion helped to establish the trust to express opinions, and we took care to make sure all students were treated respectfully.

The most common “problem” we found, especially with speakers not currently performing research in nanotechnology, was focusing on issues specifically related to nanotechnology. Many ethical issues raised by developments in nanotechnology, especially control of access to life-changing technologies, adequate education about their benefits and risks, and balancing personal and societal choices about how and when to adopt these technologies, are similar to those already faced with modern microelectronics and medicine, and date back at least to the industrial revolution. Students were, however, eager to discuss and learn about these general issues, which helped to identify nanotechnology as part of human development and not a radical departure from historical precedent. We also chose readings for discussion on the degree to which hyperbole and fictional depictions of nanotechnology impact public opinions on its relative risks and benefits.

Student response to the class, including its structure and choice of topics, was uniformly positive, and most specifically mentioned the diversity of topics and perspectives of the students and speakers under “what did you enjoy most about this class?” on the end-of-course survey. Students suggested we expand our speakers to include more practicing nanotechnologists, especially ones with experience in established or entrepreneurial companies, and someone who works in establishing and implementing policy. They also requested more focused readings. The talks that received the most positive comments were those by scientists who discussed how they had directly addressed ethical issues in their own research careers; the least well received were those that addressed parallel issues in technology or medicine rather than specifics of nanotechnology. The latter could likely be improved upon in the future with more focused instructions to the speaker and better choice of reading material.

Audience

Despite its listing as a 400/500 level physics class, the class attracted a wide variety of students, from a freshman pre-engineer to an advanced graduate student in philosophy. On the first day of classes, several students showed up to see if this was an “easy 2-credit class to fill out their schedule” – they did not return. One dozen students (from 10 different departments) took the class for credit, and several others (including post-doctoral fellows and CNT staff) audited the class on a semi-regular basis. It would be difficult to teach this class with more than about 20 students and maintain the open discussions that were the heart of the class, but the diversity of backgrounds was also essential, as is a reasonable audience for guest speakers, so that 10 students is likely the minimum for a successful class. For classes larger than 20 students, the group should meet together for presentations, but split into smaller groups on discussion days.

It is very unusual to both teach and take a class with such a wide variety of backgrounds and interests among the students, and an unanticipated benefit of the class was educating both students and faculty on different ways of learning. One (science) graduate student commented the following quarter, “By participating in a class with students from other levels of education and other disciplines, I was able to pinpoint my weaknesses in communicating scientific ideas to the general populace and improve on the means in which I do communicate.” Another

commented, “I appreciated the equality established in this course. The interdisciplinary study helps to define society and our current progress. A scientist’s perspective is different from the English major’s. The needs of all were discussed and this I feel is enjoyable and most important.”

Student Development of Case Studies

Students were assigned to 3-member teams to develop a case study for publication on the world-wide-web (and use in UW’s Frontiers in Nanotechnology class) that addressed a topic related to societal and ethical issues in nanotechnology. Teams each included at least one scientist or engineer, at least one humanist or social scientist, at least one graduate student, and at least one undergraduate student, and were selected by the instructors. Allowing time in class, and a place before or after class, for students to meet in their presentation groups was very important, since most of the students did not run into each other elsewhere on campus. Students chose the topics themselves, with advice and approval of the instructors. This fortunately ended with a reasonable coverage of important issues.

Each student team initially produced a 30-minute class presentation and discussion, after which they incorporated feedback to produce a 3-5 page written case study with references for use in the classroom. After editing by the instructors, these are now available on the world-wide-web.ⁱⁱ

Testing Case Studies in a General Class Environment

The case studies were utilized in the Frontiers of Nanotechnology class in Spring 2009. The case study, “The Paradigm Shift of Nanotechnology: Consequences of Status Quo Lab Attitudes,” which addresses issues of laboratory safety and ways to report unsafe practices, was incorporated into a class on general scientific ethical conduct. By bringing up potential differences between safe exposures to bulk and nanoscale materials in addition to more traditional issues of safety and “whistle-blowing,” the case study successfully expanded discussions from previous years into nano-specific areas. The other three case studies were discussed in a second class focusing specifically on societal and ethical issues related to nanotechnology. They dealt with cases (*i*) where one makes a personal (if not necessarily well-informed) choice to embrace nanotechnology with minimal impact on others (“Supplements with Nanoscale Ingredients”), (*ii*) where individual personal choices to embrace the technology are required to establish it, but, once established, the choice not to embrace the technology may have costs (“Visions of Bionic Lenses: Foresight for the Future”), and (*iii*) where decisions made at a corporate and/or governmental level impact how everyone becomes dependent on a nano-based technology and must deal with its environmental impact (“Solar Energy”).

The case study on supplements highlights the lack of regulation in cosmetics and supplements, as well as the unsubstantiated claims made on many manufacturers’ web-sites and advertising material, making it difficult for the consumer to make an informed decision about whether to utilize nanoscale supplements. The case study on bionic contact lenses, that may someday both monitor medical conditions and receive wireless images, brings up discussions of when a technological innovation becomes irreversible (for example, cell phones). “Solar Energy” balances the promise of reducing CO₂ emissions with the potential environmental hazards of chalcogenide-based solar cells, and led to discussion of whether to expand the use of the technology now, or wait until more environmentally benign solar cell materials are developed. All four case studies generated strong interest and discussion among students in the FN class. They also expressed a belief that both the general public and practicing nanotechnology researchers should be made aware of the issues raised, with no consensus on which were the

most important (though each listed a different topic as being most important for the general public or for the “nanotechnologist”). One student commented, “I heard a lot of new thoughts and ideas that never hit me. As a new researcher I really think [the] issues were interesting and worth a debate.”

Future Directions and Transferability to Other Institutions

Overall, the class was regarded as a success by all involved. The instructors gained a new appreciation for the complexities of societal and ethical issues and nanotechnology and for means to bridge the traditional divide between the natural and social sciences; the students gained needed perspectives and informed their future career plans; the speakers also expressed gratitude for the opportunity to be involved in this endeavor. There was a general appreciation that more students should be exposed to the concepts brought up in class to help them make educated choices about both creating and using new advances in nanotechnology.

Two factors control the frequency with which the Seminar in Nanoethics should be offered: supply (of faculty and presenters) and demand (students). On the demand side, given that only a dozen students took the class this year, it is unlikely, even with better publicity, that more than twice that number would populate a class each year; this suggests that once per year, or once every other year is a reasonable frequency. Several students in the class, however, expressed a belief that a class addressing societal and ethical issues in nanotechnology should be required for our interdisciplinary degree in nanotechnology; such a requirement has also been suggested for the undergraduate minor in Nanotechnology and Molecular Engineering that UW is currently creating. Either of these actions could double the demand for the course. Creating a requirement of an entire quarter (rather than the current week of FN) on societal and ethical issues in nanotechnology, however, will likely require extended discussions to convince students (and faculty) that their time will be well spent. A survey of researchers in the NNIN^{viii} found that only 58% either strongly or somewhat agreed with the statement that “there are significant ethical issues related to nanotechnology,” with 43% either quite or very willing to spend time learning about ethical issues related to nanotechnology and 22% only slightly or not at all willing to do so.

On the supply side, given that no more than two students in the class were from any single department, it is difficult to justify the course administratively within any single department. With the severe budget crises facing UW and other universities, adding classes into the regular curriculum usually must be paired with course elimination in the same budget line, making addition of interdisciplinary classes especially difficult. Also, classes with co-instructors from different departments are typically taught as an overload by at least one, if not all of the instructors. These issues are a real barrier to establishing this course as a requirement for an interdisciplinary nanotechnology degree at the graduate or undergraduate level, since that would require an administrative commitment that the course be taught on a regular basis, and not simply as an occasional “special topics” class.

The use of guest lecturers in this class had two distinct advantages. The first is pedagogical – they greatly expanded the range of expertise and ideas to which students were exposed, and also expanded their networks on campus. For example, one student decided to pursue an independent study course with one of the speakers, whom she might not otherwise have met. The second advantage is logistical – it enabled the instructors to complete most of the time-consuming aspects of class preparation before the quarter started, with the main responsibilities during the quarter being to read preparatory materials, attend the guest lectures, and alternate leading class discussions between the two instructors. Each instructor also prepared a lecture in her field of expertise. The format enabled teaching a new class in a field outside our primary

expertise (where creation of new lectures is normally a very time consuming activity) on top of our regular teaching, research and service activities. In the long run, with increased exposure to interdisciplinary teaching and materials, and administrative support for teaching such a class as one's primary teaching assignment, a single faculty member could teach this course as a standard 3-credit, 400/500 level class, with occasional guest speakers, including additional written assignments covering both technical and ethical issues. With increasing acceptance of nanoethics as a central topic in education of both future creators and future consumers of nanotechnological advances, it is hoped that a permanent home for this course will be found.

Table I: Syllabus for Seminar in Nanoethics, University of Washington, Winter 2009

Week	Topic
1	Introduction to Class <i>D. Bassett (UW Communication, CWD); M. Olmstead (UW Physics, CNT)</i> Introduction to Ethics <i>J. Benchimol (UW Philosophy)</i>
2	Overview of Nanotechnology <i>E. Allen (UW-CNT)</i>
3	Ethical Issues in Practicing Research: Funding, Animal Subjects, Privacy <i>B. Parviz (UW Electrical Engineering, CNT)</i>
4	Applied Ethics of Nanotechnology: Results of Survey of NNIN Users <i>R. McGinn (Stanford Management Sci. and Eng., and Science, Technology and Society)</i>
5	National and International Political Implications <i>V. Chaloupka (UW Physics, Jackson School of International Studies, and Music)</i>
6	Cultural and Religious Implication of Nanotechnology <i>C. Speed (UW Comparative Religion)</i>
7	Ways of Speaking Among Scientists about Nanotechnology and Ethics <i>D. Bassett (UW Communication, CWD)</i>
8	Ethics of Framing Issues in Nanotechnology, Learning from Medical Ethics <i>K. Fryer-Edwards and C. Riley (UW Bioethics and Humanities)</i>
9	Environmental Health and Safety Issues <i>F. Baneyx (UW Chemical Engineering, CNT)</i>
10	<i>Student Presentations</i> <ul style="list-style-type: none"> • The Paradigm Shift of Nanotechnology: Consequences of Status Quo Lab Attitudes • Solar Energy • Supplements with Nanoscale Ingredients • Visions of Bionic Lenses: Foresight for the Future

References

- i. *Education in NT: Launching the First Ph.D. Program*, Viola Vogel and Charles T. Campbell, *Int. J. Engineering Education*, 18 (5): 498-505 (2002).
- ii. *Nanoethics on the World Wide Web: Helping Faculty Enhance Graduate Education*, Center for Workforce Development, University of Washington. Available on the web at <http://depts.washington.edu/ntethics/casestudies/index.shtml>
- iii. Unpublished data, UW Center for Workforce Development.
- iv. UW Center for Nanotechnology, Nanotechnology Seminar 2005-2006. <http://www.nano.washington.edu/seminars/2005-06.pdf>
- v. *On Being a Scientist: A guide to responsible conduct in research*, Committee on Science, Engineering, and Public Policy, Nat'l. Academy of Sciences, Nat'l. Academy of Engineering, and Institute of Medicine (National Academies Press, Washington, DC) available on line at http://www.nap.edu/catalog.php?record_id=12192
- vi. *Nano Futures Scenarios*, Center for Nanotechnology in Society, Arizona State University, available online at <http://cns.asu.edu/nanofutures/index.html>
- vii. Further information available at <http://depts.washington.edu/ntethics>
- viii. "Ethics and Nanotechnology: Views of Nanotechnology Researchers," Robert McGinn, *Nanoethics 2* (2008) 101–131.

The Ethics of Identity: What is the Psychological Utility of Narrative Cases in Ethics Education for Developing a More Culturally Diverse Nanotechnology Workforce?

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Abstract

Throughout the world nanotechnology investments are large and have grown exponentially in a very short period. If science is a human enterprise whose decisions impact all of mankind, questions of inclusion and diversity in nanotechnology research and development must be pursued. Within science and engineering workforce training, the U.S. Federal Government requires ethics education of its researchers and developers that they fund and who are responsible for training graduate students and other professionals (America Competes Act, 2007). And yet, there are very few existing models within graduate education for how to provide a robust ethics education in the face of the complex practice of science and engineering research, as well as the continuously shifting complex relationships among science, engineering, technology and the increasingly diverse society. We argue that a life story model of idiographic narrative case methods of discovery and learning can be used within ethics education of nanoscientists. This model could be used to work through ethics problems of inclusion and cultural diversity in nanotechnology employing analysis of the narrative construction of individual's life review and experiences as they traverse their educational and professional experiences as they became part of the nanotechnology workforce. The theoretical orientation that supports the use of narrative cases in ethics education of the nanotechnology workforce includes consideration of culture, identity, and context. There is compelling evidence that within higher education that diversity has positive impacts on key areas of learning and moral development of students which would be value added in making even stronger nanoscientists to solve the world's most pressing problems.

“The final responsibility for each life is always the responsibility of the person whose life it is”
(Appiah, 2005; p. 35).

There are two parallel developments in the global landscape that are important to consider in the equation of nanotechnology ethics. The first concerns nanotechnology investment and the second centers on the composition of the world. Throughout the world nanotechnology investments are large and have grown exponentially in a very short period (see Figure 1). Between 2001 and 2009 the United States' federal investment in nanotechnology research and development grew 500% from 375 million dollars to 1.5 billion (www.nano.gov). This tremendous investment and growth signals the centrality of nanotechnology research and development to the present and future of the global economy and thus the workforce. This

explosion of investment is occurring at the same time that there are dramatic demographic shifts both within the United States and throughout the rest of the world in the population of people who are non-White. Moreover, the U.S. Census projects that the U.S. will be more racially and ethnically diverse with 54% of the population being from groups who currently are considered “minorities” (United States Census Bureau, 2008). Given that the science and engineering workforce is currently dominated by individuals who are White, a trend that has persisted for decades (see Figure 2), these demographic shifts are particularly significant. If science is a human enterprise whose decisions impact all of mankind, questions of inclusion and diversity in nanotechnology research and development must be pursued. Nanotechnology, like all technology and science is not self-directional. Instead, the nature, type, and priority of the questions, solutions and applications pursued by researchers and developers are given direction by human beings. And it is in this way that nanotechnology inclusion and ethics intersect.

The purpose of this paper is to make a theoretical argument with practical applications. We argue that narrative cases have utility for ethics education of the nanotechnology workforce because of the storied nature of cognition, the positive learning outcomes associated with cultural diversity and the ethics of identity. Our posture on ethics, adopts an orientation by which educators of ethics do not focus their teaching on the rightness or wrongness judgment of an ethical problem or as a set of rules. Rather, ethics problems are thought of as human constructions through which students should work themselves in the place of the actors, pursuing critical thinking about the complicating action of the story plot and contemplation about other narrative features of the ethics problems including the setting and characters represented in the narrative. This approach to ethics is based on a narrative ethics model created at Howard University (Broome, Segun, and Winston, 2009) that allows for the individuality of identities of humans to be expressed and used as part of the process of working through ethics problems in science and engineering. This is a particularly promising approach for ethics education in a fast paced and leading edge area of science and engineering like nanotechnology.

Narrative Ethics in Graduate Education and Professional Development of the Nanotechnology Workforce: What are Narrative Cases and how can they be used?

Ethics education in science and engineering encompasses many issues and many constituencies, including: pre-college; undergraduate; graduate and postdoctoral students; junior and tenured faculty; technicians and administrators; and practicing scientists and engineers outside academe. Ethics education has implications for the institutions in which all of these individuals and groups study and work, as well as for other organizations and associations. Ethics issues arise in the practice of science and engineering as well as in the complex relationships among science, engineering, technology and society. To address this variety of issues and constituencies, educational practice needs to draw from relevant research, including work in practical and professional ethics and theory of action, pedagogical theory, and appropriate theory and knowledge from social and behavioral sciences.

-National Science Foundation (2008) <http://www.nsf.gov/pubs/2008/nsf08530/nsf08530.pdf>

Within higher education, there have been numerous debates about how to best educate the next generation of professionals. In no areas more than science and engineering has this debate shifted almost in parallel to the nations’ economic development, global positioning and political agenda. As America struggles to maintain its position as a world leader in science and engineering, nanotechnology is the core interdisciplinary commodity in solving most of the world’s most pressing problems. Nanotechnology research and development is vital in

discovering solutions to high priority problems that impact everyday living including those associated with energy, health, water, security, and technological innovation. Moreover, it has been estimated that within the United States since World War II, about half of the world's economic growth has been due to technological innovation (National Academy of Science, 2007). Within science and engineering workforce education and training in the United States, ethics education is part of the cornerstone of what the federal government requires of its researchers and developers that they fund who are responsible for training graduate students and other professionals (America Competes Act, 2007). And yet, there are very few existing models within graduate education for how to provide a robust ethics education in the face of the realities of the fast paced and complex practice of science, engineering and nanotechnology research, as well as the continuously shifting complex relationships among science, engineering, technology and society (see the Nanoethics on the World Wide Web Project for an exception <http://depts.washington.edu/ntethics/about/index.shtml>). How might stories about lives and experiences of persons who are currently in the nanotechnology workforce be used as one model among many in ethics education in which the nanotechnology workforce is trained and works?

We argue that a life story model of idiographic narrative case methods of discovery and learning can be used within graduate, professional, and continuing ethics education. This model can be employed in formal and informal learning settings to work through ethics problems of inclusion and cultural diversity in nanotechnology that can be interpreted through interrogating the narrative construction of individuals' life review as they traverse their educational and professional experiences in becoming part of the nanotechnology workforce.

What is a case, why and how can cases be used in nanotechnology ethics education? A case is defined as a bounded system and can refer to the individual person, a school, or a program unit of analysis for example. The theoretical and methodological orientation of using a case approach to ethics in nanotechnology is grounded in psychological science theory and research within personality psychology. At its founding, Allport (1937) and Murray (1938) identified personality psychology as the field of psychology's holistic subarea. The mission of personality psychology as they described it was person centered with a focus on the whole person as primary unit of study, suggesting the unity, coherence, and wholeness are properties of human lives (McAdams & Pals, 2006).

This focus on an idiographic approach to human personality strives to discern specific and individual patternings in human lives and therefore, uses cases. This type of case study method has also been called the single subject design. This level of analysis most typically seeks to uncover understanding about the human uniqueness levels of personhood. In contrast, nomothetic approaches that characterizes most of the rest of the field of psychology have the aim to discover and test general principles or laws of behavior. Here the goal is most typically to understand how all persons are alike, as well as individual and group level differences. Within this research design, researchers most often employ experimental or survey methods in which they sample a large and representative group of individuals and look for individual differences between and across variables and interactions in order to draw conclusions about general principles of human behavior and cognition. Although no one approach is inherently better than the other, many scholars criticize the focus on the single case designs that are characteristic of idiographic research in psychology. Over time, this criticism has been led by the field of psychology's obsession with trying to position itself and be viewed by others as a natural science, rather than a social one. What is most interesting about this criticism of ideographic methods and the single subject design is that many of psychology's most widely

used theories in research were developed with an origin in idiographic methods of inquiry, especially the single subject design (Conner, Barrett, Tugade & Tennen, 2007).

Cases have been used in multiple ways for both research and teaching. As a research method, the case study is a common method in psychology, sociology, political science, anthropology, social work, business, education, nursing and community planning (Yin, 2009). Yin (2009) suggests that one reason for interest in the use of this method is that it allows “investigators to retain the holistic and meaningful characteristics of real life events” (p.4). As a teaching method, cases are used as a tool across a number of fields including but not limited to law, business, medicine and public policy (see Garvin, 2003; Towel, 1969; Windsor & Greanias, 1983). Unlike the case in the research study, the teaching case is not necessarily always a description of actual events within a person’s life. Instead, they often are composed by either a professional case writer or professor with the goal of using the case as a tool or to establish a framework for students to apply theories, to discuss ideas and to debate key issues that are the focus of a professor’s student learning objectives. We propose that cases should be used to explore narrative ethics within graduate education and professional development settings through the combining the goals and strengths of using cases in both teaching and research. The University of Washington’s Nanoethics on the World Wide Web Project has been pioneering in its use of cases to teach nanoethics with the cases being developed by graduate students.

There are several techniques that can be used to collect information about the experiences of scientists, engineers and others currently in nanotechnology careers to create case material and expand experiential understanding for graduate and professional education. There are a few narrative case research instruments employed by psychologists that are particularly useful in this regard: the Life Story Interview (McAdams, 1997), the Guided Autobiography (McAdams, 1997) and the ISRL Nanotechnology Education and Professional Development Strategic Interview (Harris & Winston, 2009).

These approaches are very similar in nature to those developed within the Identity and Success Life Story Research Method (ISLSRM) specifically to study the life experiences of successful scientists and engineers (see Winston, Philip, & Lloyd, 2007). ISLSRM is a case study research method developed at Howard University in the Identity and Success Research Laboratory (<http://www.coas.howard.edu/psychology/labs.html>). The ISLSRM is designed to do an in-depth study of an individual’s life and adopts a psychological, person-centered approach. A person-centered research strategy views the person as the central unit of analysis and takes on an integrated view of the individual as a whole functioning person who develops psychologically over time within multiple contexts.

There are many different models for how these life story methods can be used in the context of graduate education and professional development learning modules in nanoethics education. Students could be assigned to conduct an interview of a current nanoscientist using one of these narrative data collection tools. Participants for these interviews could be recruited through national science and engineering societies, as well as within specific nanotechnology consortium, centers and businesses. Using these instruments would result in life story data in narrative form that could be used in several ways.

It could be used to gain insight into general educational and personal experiences that compose the nanoscientist journey to a career in nanoscience. Equally plausible would be to identify instances within those experiences that have a narrative structure or tell a story that could be discussed as a problem of ethics. For example, in a Narrative Engineering Education Project

conducted in the Howard University Identity and Success Research Laboratory, narrative data collected from Dr. Gary Harris, a leading nanoscientist, provides an illustration of life story data collected through using one of these instruments that can be used as case data to work through an ethics problem.

When I was in college another thing that happened is that we got together and we found out how a lot of students were getting good grades. And they were involved in fraternities and the fraternities had all the exams. And so that summer, I remember the summer of my junior year, we went to the director of the engineering program and we asked if we could get a copy of all the notes from his fraternity house, because they had all of the notes on all the professors. We got the notes. That fall the Black grade point average in engineering was higher than the White grade point average.-Dr. Gary Harris (2009), Professor of Engineering Howard University and Director of the Howard University Nanoscience Engineering Facility

This narrative includes several different classes of actors. It includes the person telling the story, other Black students, the Dean, engineering professors and students who had access to the fraternity house notes. This narrative case could be examined and discussed in a science and engineering graduate education or professional development seminar on ethics starting with asking each student to answer the following question: what is this narrative about? Depending on a student's worldview and experiences there are many answers that could be provided. For example, one student may interpret this story to be simply about getting notes to study for engineering exams. Another person may interpret it to be about inequality in access to resources because of not being included in a social group or because a person or group of people are in one social group and not another. Also, it could be interpreted as a story about social identity and racial pride in the success of the group to which the storyteller belongs. Ethics questions about notes being available to some and not to others may be at the crux of yet another student's interpretation of the story.

Whatever the interpretation of the story that is made, it is likely different people with different experiences, cultures and worldviews will have distinctive interpretations. This provides an opportunity for participants in the discussion to perspective take and work themselves through the problem in the story in place of the Dean as an actor, the storyteller, those in the fraternity house who had the notes and other characters that may be identified by the interpreter of the story. This type of social and ethics problem within science and engineering, as well as nanotechnology education represents not a problem of science and engineering practices per se. Instead, it represents the class of ethics problems that NSF refers to as ethics problems that arises from "the complex relationships among science, engineering, technology and society" (National Science Foundation, 2008).

The life story and other narrative experiences of a culturally diverse set of cases who are in the nanotechnology workforce could provide an important tool kit from which students and others engaged in nanotechnology education and professional development could benefit psychologically. This psychological gain could be in form of a strengthened identification with nanotechnology as a reasonable occupational goal for that person, or an increased sense of achievement motivation to model or transcend the experiences of success that may be included in a story within a narrative case used for this purpose.

A second model but slightly more complex for infusion of narrative ethics into graduate education and professional development setting is to engage individuals in formal narrative analysis of the structure and thematic content of a collection of narrative cases of the life

experiences of individuals in nanotechnology. This would be considered a research project much like what is done within the fields of psychology and education. Narratives could be collected using one or all of the narrative tools and then analyzed using a narrative structural analysis. Such an analysis would allow for commonalities and differences of experiences in terms of the settings, complicating actions or plots, and actors in narratives of experience of individuals in the nanotechnology workforce. This would enable the generation of a dataset of experiences that could be used to expand understanding of the educational experiences, as well as professional development experiences along the pathway to becoming a part of the nanotechnology workforce. Included in these data would be experiences that could be used as instances of ethics problems that could be worked through for case method teaching or other forms of professional development.

Cultural Diversity, Cognitive Growth, Learning Outcomes and Values: What are the psychological theoretical underpinnings of the use of narrative cases in ethics education of the nanotechnology workforce?

The theoretical orientation that supports the use of narrative cases in ethics education of the nanotechnology workforce includes consideration of culture, identity, and context. Culture can be defined in multiple ways. At the heart of all definitions of culture and most important to understanding the psychology of culture is the idea that culture is multidimensional in its inclusion of attitudes, behaviors, symbols and meaning that are transmitted across time and persons. A distinction in the conceptualization of culture within the field of psychology centers around the emphasis on “difference” between groups versus culturally constructed worlds where there is a focus on the context dependent nature of making interpretation about persons and lives in which “meaning” of symbols and acts are of primary concern. It is this later conceptualization that is most often placed within the rubric of cultural psychology and the former is designated as cross cultural psychology. Taken together, we define culture using both a cultural psychology and cross cultural orientation and define it as a meaning system that is both personal and public that defines people, lives, values, identity, traditions and places across time and space.

Culture is important to consider in the context of ethics education in the form of cultural diversity. Within social psychology, there is compelling evidence that within higher education diversity has positive impacts on key areas of learning and moral development of students. This evidence has been most carefully and comprehensively synthesized by Dr. Patricia Gurin in her expert report in two of the most important recent Supreme Court cases on affirmative action in higher education: Gratz, et al. v. Bollinger, et al., No. 97-75321 and Grutter, et al., v. Bollinger, et al., No. 97-75928. Based on a synthesis of a collection of studies, she developed an analysis of how college students are changed by their college experiences. This study draws on archival research data from the University of Michigan, as well as data collected from students attending colleges and universities across the country. In sum, Gurin (1999) describes the findings from this analysis, as well as others in the research literature in the following way: (1) structural diversity had significant positive effects on classroom diversity and interactional diversity among all students; (2) diversity in classroom settings and in informal interactions with peers showed the greatest engagement in active thinking processes, growth in intellectual engagement and motivation, as well as intellectual and academic skills; (3) students who experienced diversity in classroom settings and informal interactions showed the most engagement in various forms of citizenship, were more engaged with people from different races and cultures in their future personal and workplace lives and were better able to understand and consider multiple perspectives, deal with the conflicts that different perspectives sometimes create and appreciate

the common values and integrative forces that harness differences in pursuit of the common good.

These results imply several important things relevant to nanotechnology ethics education adopting a narrative case approach. The use of narrative cases of experiences can provide benefits to learning outcomes and skill development that have the potential to strengthen the overall preparation of these students to be better problem solvers and innovative thinkers---both important to nanotechnology research and development. This includes the positive impact of diversity on creating students who learn more and think in a deeper and more complex ways which were found in Gurin's analysis of the available data. In addition, using narrative cases that include cases that have been constructed by individuals who are from cultural backgrounds different from the other students can create a diversity within classrooms in which ethics is taught that are not themselves characterized by a diverse student body. This is a very likely reality still in most of the nations' research universities in which the next generation of nanoscientists are currently being trained---places that often do not include any African American and Latino students, and few women. In a sense, these narrative cases then serve as the source for diversity and the resultant learning benefits to occur. Either model of narrative case use described previously would allow this goal to be achieved.

The psychological core to all of this rests in identity. Within psychology there have been many conceptualizations offered of identity, most with the common element of answering the question: Who am I? This question is pursued psychologically by the individual with a past, present and anticipated future mental gaze. What is common also to these conceptualizations is that each recognizes both a nature and function of identity. In terms of the nature of identity, most conceptualizations define identity as personal, social and contextualized. In this sense, identity as personal is defined as a sense of self. The most influential early conceptualization of this sense of self was as a "direct feeling of regard for [our] own pure principle of individual existence" (James, 1890; p. 318). In contrast, to this conceptualization, a contemporary definition defines personal identity as "the accumulated store of relatively enduring yet continually modifiable temperamental, iconic, symbolic, and phenomenological content that has been more or less differentiated at any given point during the life span whether or not this content is immediately available to focal awareness" (Peck, 2007; p. 1144). One element of personal identity that is important is contextualized identity. This is defined as the relation between the person as a whole as subject and the context as a whole as object. In other words, it is the integration of the external environment with this relatively enduring temperamental, iconic and symbolic content that has been activated and represented phenomenologically. Social identity refers to how a person thinks about herself as a member of social groups. These group memberships could be racial, ethnic, sorority, or academic groups for example. Tajfel and Turner's (1986) highly influential social identity theory posits that a person used social identity to serve at least three functions: to categorize people into groups based on assumed shared belief, experience or characteristics; to identify with certain groups; and to compare those groups we belong to with other groups, typically thinking more highly of the groups to which the person belongs.

A less often adopted conceptualization of identity that has particular utility for our narrative case approach to ethics education in nanotechnology is conceptualizing the form of identity in terms of a storied element of human personality. Within McAdams' (1985) life story model, identity is conceptualized as storied. More specifically, the life story model explains that persons engage in identity work of selective synchronic and diachronic integration of experience in the form of a story of self. From this perspective, human personality is not only composed of dispositional traits, adaptations characteristic of the person in time, place and role, but it also includes an

internalized and evolving narrative of self (see McAdams & Pals, 2006). As a way to bring unity and purpose to life, a person has the interpretive power as an author of her story of self to internalize, dismiss, incorporate and or combine internal and external stimuli that answer the question “Who am I?”. From this perspective, Bruner (1990) argues that persons’ narrative construction and symbolic meaning depends on the existence of language and the human capacity to internalize language and to use a system of signs for interpretation.

We believe that it is this storied form of identity that is a useful heuristic in seeing where the rest of the multidimensionality of identity comes together. It is through an individual’s process of seeking questions about the purpose of his or her life, how to bring unity in understanding self, other and world across various roles and experiences that the answer to the question “Who am I?” becomes more fully explored. We assert that this storied form of narrative identity creates an opportunity for ethics education largely because it is human nature for individuals to think in storied terms. No lessons are required. Therefore, if narrative cases are used of individuals constructing a sense of self, other, the world, their educational experiences and professional development experiences in nanotechnology then another person may have access that would not otherwise be granted into the mind, life and experiences of another person. This could be a person who is of a similar or different cultural background. Or it could be a person who is further along in the nanotechnology profession. It is this modeling, that creates a biographical mirror into many issues of decision, ethics and critical analysis about what it really means to be a nanoscientist within the world in which we live and the process of “becoming” a nanoscientist. It has been suggested by some psychologists that a core element of occupational identity development is the merging of the biographical experience with the drives and goals toward an imagined future (Kielhofner, 1995). From this perspective, narrative cases can serve the dual goal of inspiration and motivation, while at the same time allowing the person to imagine his or her future in the profession.

Kielhofner (1995) conceptualizes occupational identity as the degree to which a person has internalized a positive sense of self understanding has an image of the kind of life one wants, sees oneself in a variety of occupational roles and has interests, values and confidence. This kind of self-understanding and perspective taking on a forward gaze depends on the person engaging in the process of identification and making sense of previous life experiences. Expanding the cultural diversity in the nanotechnology workforce depends on individuals who are currently not participating to begin to see nanotechnology as part of their imagined self and future. Narrative cases open up many possibilities for nanotechnology ethics education but also for nanotechnology literacy for the broader general public. Such a public understanding of nanotechnology has great import for the future of this area of research and development. The National Nanotechnology Initiative (see www.nano.gov) serves as a great example of increasing public understanding of nanoscience and we believe our narrative case approach can make a complementary contribution.

The age of many science and engineering students serves as an ideal developmental period in which to engage in narrative ethics of the type we are recommending. In his highly influential identity theory, Erickson (1968) theorized that identity is best developed when individuals are afforded the opportunity for a psychosocial moratorium in which they can experiment with various social roles before making a commitment to an occupation. The students in graduate school who are pursuing science and engineering careers in nanotechnology areas likely have made a commitment to this career to some degree but are probably still trying to work out the nuances of who they want to be as professionals, as well as what they value. Experiencing cultural diversity of thought that can emerge in a classroom narrative ethics discussion or that is represented in a narrative case certainly can serve to add some complexity, depth and

challenge as they further solidify the values and professional dispositions associated with their occupational choices within the nanotechnology workforce.

Within this narrative case model of nanoethics education, the cultivation of particular values toward the occupation of nanotechnology and the development of a professional disposition are where identity and culture intersect. From this perspective, there is an ethics in developing a sense of self and identity as a nanoscientist and part of the nanotechnology workforce. It is graduate education and other forms of early professional socialization that can be catalytic in creating certain values that promote individuals to adopt a personal responsibility for expanding the cultural diversity of the nanotechnology workforce. Moreover, there may be themes and plotlines in the narrative cases that are used in nanoethics education that can serve as examples of the psychological and occupational benefits of individuals taking responsibility for others in the profession. After all, a very significant portion of the training and research collaboration experience of scientist, engineers and nanoscientists is mentoring of another person.

The idea that we make our lives and in that human project can contribute some psychological or material resources to others who are in the process of crafting their lives is at the heart of the ethics of identity. The term “ethics of identity” was first introduced by Appiah (2005), who introduces it to explore the ideas of the fusion between identity and ethics in individuality of crafting personal and political lives. In our work with narrative ethics and nanoethics in particular, the ethics of identity becomes a personal exploration of questioning about not only moral responsibility to encourage and motivate others toward nanotechnology careers, but instead becomes a broader social project for the society in which we live that depends so heavily on nanotechnology research and development. Both informal and formal education settings are ripe for the lives, work and experiences of nanoscientists to be introduced. We believe that people are doing this and even more can. An example of this kind of personal responsibility emerging from a person’s own life experiences that fuses with a professional obligation to the next generation of nanoscientists can be found in the ISRL Narrative Engineering Project’s case Dr. Gary Harris that we previously mentioned. In an interview he describes his motivation for creating a nanotechnology mobile lab, the Nanoexpress, that he has taken to elementary and secondary schools throughout the country with more than 14,000 students gaining experience within this mobile lab.

Interviewer Question: *What sort of responsibility do you believe you have or don't have with respect to increasing the numbers of African Americans and females in nanotechnology and engineering generally?*

Dr. Gary Harris: *Well, I try to go back and look at my own career development to a certain extent and I think about to a certain extent it's sometimes about the little things. And that's why I developed the mobile lab to go out and maybe touch one person. Or maybe reach in a high school of 100 kids maybe reach one person or two people. And I see that as my role to go out and just expose people, tell them what the possibilities are. I said, why don't we just figure out how we can take the lab to them. When I first mentioned this to some of our colleagues in our network, they laughed at me. They said you are going to build a lab that you can take to a high school? Are you crazy? Are out of your mind? And it is going to be a functional lab? That will never work. And they changed their mind, however when they saw the lab and they just got a chance to see literally the thousands of people that we have had the opportunity to touching.*

What is the value in being motivated to touch one or two high school students from diverse cultural backgrounds in increasing their knowledge, interest and experience of nanotechnology?

The goal in expanding the cultural diversity of nanotechnology cannot be to achieve isolated numbers and token inclusion. However, it is the psychology of identity that is at work here---it is the ethics of identity of the storyteller and it is also the psychology of identity of the target of inspiration and interest. Also, it is interesting that others did not think it could work but there was a motive, goal and self-concept of ability to pull it off that mattered to Dr. Harris. He thought it was important enough to pursue...even if his peers of nanoscientists thought it would never work. And now more than 14,000 students were exposed to some of the previously unimaginable possibilities for human life created by nanotechnology research and development.

In sum, we believe that narrative cases of nanoscientists have value for the individual and for society. And we are most encouraged by what the simple act of a single nanoscientist can do to expand the possibilities for a young student to see him or herself as a nanoscientist or to even have the opportunity to know what nanotechnology is in this world that is constantly moving and changing at the hand of the innovations of nanotechnology. In many ways, to maintain a democratic society depends on nanotechnology literacy among the broader public who will be called upon to make decisions and take stances on nanotechnology related issues impacting their communities and those issues represented by and legislated by their elected officials who represent their interests.

Conclusion and Implications

Working at the nanoscale, scientists today are creating new tools, products, and technologies to address some of the world's biggest challenges, including clean, secure, affordable energy stronger, lighter, more durable materials low-cost filters to provide clean drinking water medical devices and drugs to detect and treat diseases more effectively with fewer side effects lighting that uses a fraction of the energy sensors to detect and identify harmful chemical or biological agent techniques to clean up hazardous chemicals in the environment.

http://www.nano.gov/Nanotechnology_BigThingsfromaTinyWorldspread.pdf

Ethics education is a complex enterprise, as are science and engineering. Nanotechnology is a very specialized interdisciplinary area that merges people collaborating from science, engineering and many other disciplines. This includes individuals who are undergraduate, graduate, postdoctoral students, as well as junior and tenured faculty, technicians, administrators, practicing scientists and engineers outside of academe (NSF, 2008). The demographic shifts in the nations' population of non-White citizens will create a reality of a nanotechnology graduate education and workplace that includes people who are more culturally diverse than ever before in history. Taken together, these facts suggest that ethics education in nanotechnology demands a very robust and multidisciplinary collection of tools, resources and methods. Theoretical orientations and narrative methods from the field of psychology can make a contribution to ethics education in science and engineering.

We have argued that personal experience represented through narrative is a central psychological element in the ethics of the expansion and sustainability of cultural diversity, as well as the promotion of literacy, interest and occupational development in nanotechnology. Storytelling is a natural psychological act. All humans have the cognitive capacity to not only tell stories about personal experience and but to interpret their meaning. They also have the capacity to understand stories told by other people. The larger problems of the ethics of identity associated with the complex relationships among science, engineering, technology and living in a culturally diverse society can be more fully illuminated through this use of narrative cases. And employing idiographic narrative case methods of discovery and learning within graduate,

professional, and continuing education to explore the ethics of identity in the nanotechnology workforce is novel.

As the United States struggles to maintain its advantage as the world's leader in science and engineering generally, and nanotechnology specifically, it will have to face the realities of its long exclusion of some of the nations' best talent of its pool of non-White citizens. In fact, the National Academy's Report, *Rising Above the Storm: Energizing and Employing America for a Brighter Future*, recommends that we "make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world". Among the best and brightest are those who are from cultural groups currently underrepresented in science, engineering and nanotechnology specifically including African Americans and Latinos.

We contend that psychologists have a role to play in the strategic efforts to address ethics and expand the possibilities for a more culturally diverse workforce, as well as the promotion of understanding difference across cultures within the nanotechnology workplace. Though narrative psychology is not intuitively relevant to science and engineering, it holds tremendous promise in ethics graduate education because all humans regardless of cultural background and life experience can understand story. What that story means will differ by individuals' life experiences and culture. But it is that very reality that makes the ethics of identity and story in nanoethics such a compelling and promising new direction for contributing to the cultural diversity of the nanotechnology workforce. The nation is depending on such creative and novel nanotechnology ethics education innovations and so is the future of our nanotechnology driven economy.

As important as issues of hazards and safety are in nanotechnology research and technology development, the psychology of inclusion and cultural diversity is of equal importance if our goal is to create a truly democratic scientific society. In our work with narrative ethics and nanoethics in particular, that the ethics of identity becomes a personal exploration of questioning about not only moral responsibility to encourage and motivate others toward nanotechnology careers, but instead becomes a broader social project for the society in which we live that depends so heavily on nanotechnology research and development. Each life starts out with many possibilities. Nanoethics education should instill in each of its students a core value that no man or woman shall not see participation in the nanotechnology workforce as out of the question for his or her life. It is this ethics of identity that a narrative case approach to nanoethics can provide.

References

- Allport, G. W. (1937). *Personality: A psychological interpretation*. New York: Holt, Rinehart & Winston.
- Appiah, A. (2005). *The ethics of identity*. Princeton: Princeton University Press.
- America Competes Act: A bill to invest in innovation and education to improve the competitiveness of the United States in the global economy. 110-69 S.761 (2007).
- Broome, T., Gbadegesin, S. & Winston, C.E. (2009). Narrative Ethics: Psychological and Philosophical Undercurrents. Unpublished Manuscript.
- Conner, T.S., Barrett, L.F., Tugade, M.M. & Tennen, H. (2007). Idiographic Personality: The theory and practice of experience sampling: In (Eds.), R. Robins, R.C. Fraley & R. F. Krueger. *Handbook of Personality Research Methods* (pp. 79-96). New York: Guilford Press.
- Garvin, D.A. (2003). Making the case: Professional education for the world of practice. *Harvard Magazine*, 106(1), 56-107.
- Gurin, P. (1999). Expert Testimony: Gratz, et al. v. Bollinger, et al., No. 97-75321 and Grutter, et al., v. Bollinger, et al., No. 97-75928 (1999). *Equity & Excellence in Education*, v32 n2 p36-62.
- Harris, J. L. & Winston, C.E. (2009). ISRL Nanotechnology Education and Professional Development Strategic Interview.
- McAdams, D. P., & Pals, J. L. (2006). A new big five: Fundamental principles for an integrative science of personality. *American Psychologist*, 61, 204-217.
- McAdams, D. P. (1995). *The life story interview*. Retrieved January 10, 2006, from <http://www.sesp.northwestern.edu/foley/>
- Murray, J. M. (1938). The conscience during adolescence. *Mental Hygiene*, 22, 400-408.
- National Science Foundation (2008) Science and Engineering Indicators <http://www.nsf.gov/pubs/2008/nsf08530/nsf08530.pdf> .
- National Academy of Science (2007). *Raising above the storm: Energizing and employing American for a brighter future*. Washington DC: National Academy of Science.
- National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, 1975–2006. <http://www.nsf.gov/pubs/2008/nsf08530/nsf08530.pdf>
- Tajfel, H., & Turner, J.C. (1986). The social identity theory of intergroup behavior. In S. Worchel & W. Austin (Eds.), *Psychology of intergroup relations* (pp. 7-24). Chicago: Nelson Hall.
- Towel, A. R. (1969). *To student administrations by cases*. Boston: Harvard University Business School.

Peck, S. C. (2007). TEMPEST in a Gallimaufry: Applying multilevel systems to person-in-context research. *Journal of Personality*, 75(6), 1127-1156.

United States Census Bureau (August 18, 2008). An older and more diverse nation by midcentury.<http://www.census.gov/PressRelease/www/releases/archives/population/012496.html>

Windsor, D., & Greanias, G.(1983). The public policy and management program for case/course development. *Public Administrative Review*, 26, 370-378.

Winston, C.E., Philip, C.L., & Lloyd, D. L. (2007). Integrating Design Based Research and the Identity & Success Life Story Research Method: Toward a new research paradigm for looking beyond the digital divide and race self complexity within the lives of Black students. *Journal of Negro Education*, 76(1), 31-43.

Yin, R. K. (2009). *Case study research: Design and Methods* (4th edition). Thousand Oakes, CA: Sage Publications.

Figure 1 Millions of Dollars in Global Investment in Nanotechnology Research and Development in 2005

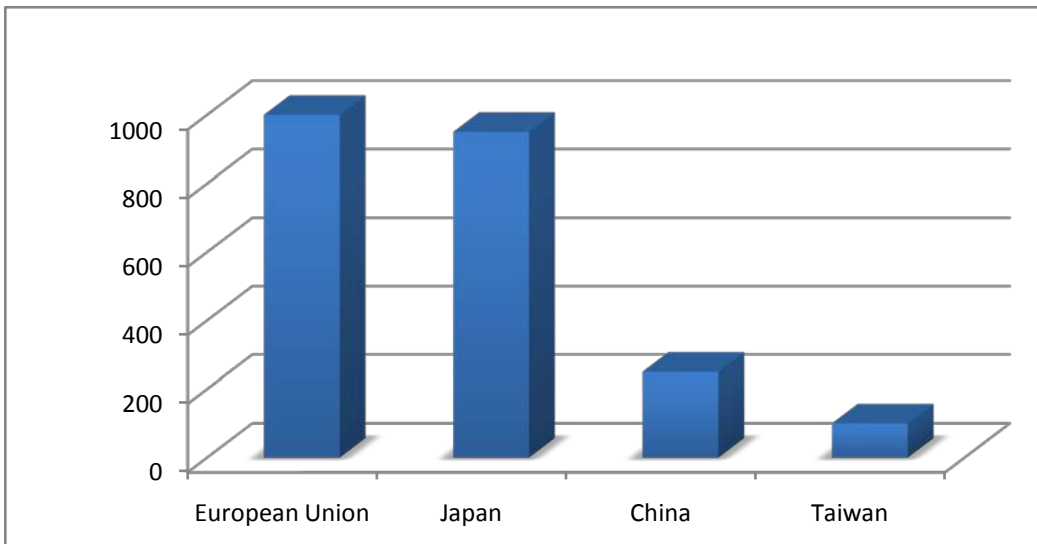
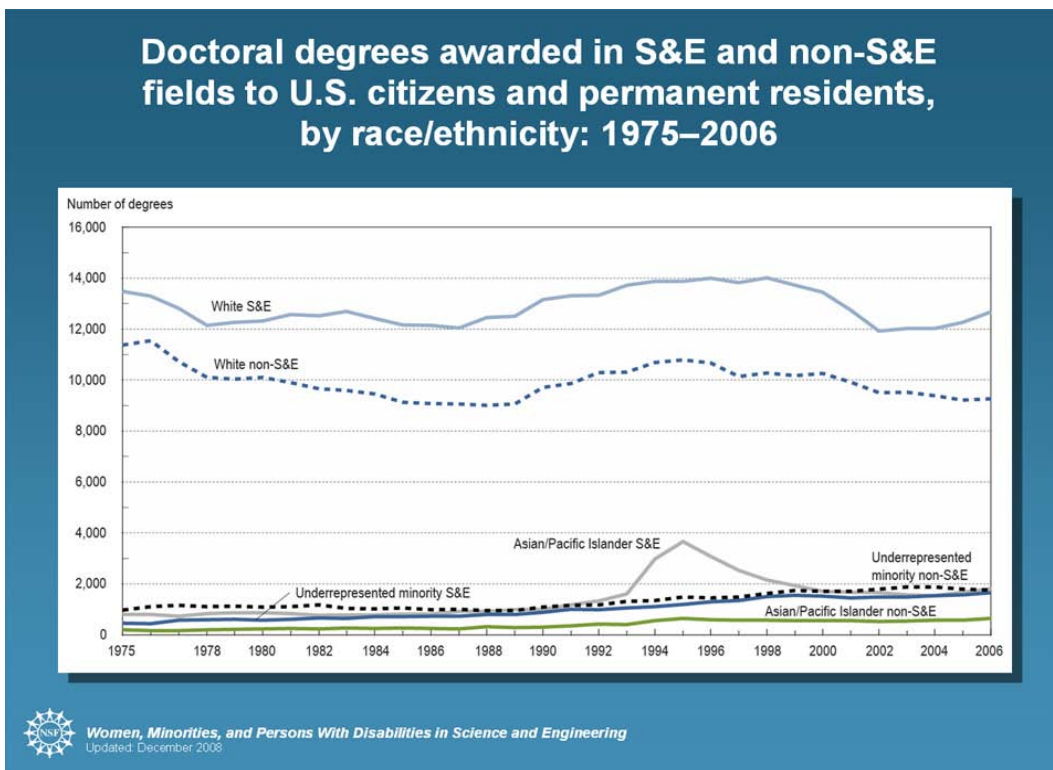


Figure 2 Doctoral degrees awarded in Science and Engineering (S&E) and non-S&E fields to U.S. citizen and permanent residents by race/ethnicity: 1975-2006



NSF Women, Minorities, and Persons With Disabilities in Science and Engineering Updated: December 2008

National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, 1975-2006.