"Catastrophic Risks: Reflections on the Domination of Nature"

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Abstract

The project known as the domination of nature, as formulated by Francis Bacon at the beginning of the seventeenth century, is the essence of modernity. Here the progress of modern science has been envisioned as delivering to humanity infinite operational power in the world through a complete knowledge of natural processes. The internal contradiction in this project is that there is too little corresponding progress in the capability of the human collectivity to manage the "downside risk" inherent in these operational powers. This theme is explored with reference to biotechnology and nanotechnology, where the objective of knowledge is to enable us to create and modify at will biological entities, as well as self-assembling mechanical entities, *ab initio* through recombinant DNA techniques. I argue that a new category of risks is created by these forms of knowledge, called "moral risks," which threatens the ethical basis of human civilization; these are also "catastrophic risks," in that their negative and evil aspects are virtually unlimited. From a practical standpoint we must now ask whether our institutional structures, including international conventions, are robust enough to be able to contain such risks within acceptable limits; or alternatively whether these risks themselves should be regarded as unacceptable, a position which could impel us to seek to forbid individuals and nations from acquiring and disseminating the knowledge upon which those technologies are based.

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Introduction: The Domination of Nature as the Essence of Modernity.

> Only let the human race recover that right over nature which belongs to it by divine bequest, and let power be given it; the exercise thereof will be governed by sound reason and true religion.
>
> *Francis Bacon*

"The Domination of Nature" was the title of my Ph.D. thesis, completed in 1969 at the University of California, San Diego under the supervision of Herbert Marcuse, and also the title of the expanded book-length study first published under the same title in 1972.[1] [2] There I argued that "mastery over nature" was a vital subterranean theme in all of modern thought after the Renaissance, a theme most clearly articulated in the work of the English philosopher Francis Bacon (1551-1626). Bacon separated this concept from its roots in two different traditions, Christian theology (the Book of Genesis) and alchemy, thoroughly secularized it and made it respectable, and associated it with the new science of nature. His new science, like Galileo's, was grounded in a practical and experimental orientation to the world. He sought, in short, to read the book of nature not as a code which when interpreted properly confirmed the tenets of religious belief, but rather as an operational manual which, correctly drafted, would increase humanity's "power." Although often misleadingly called power *over* nature, as Bacon knew this is power attained *through* an understanding of natural processes of a special kind, namely, one that has been stripped of any theological or philosophical overlay. This power was understood as the ability to steer natural forces, systematically and without limit, towards the satisfaction of human wants, encompassing – in Bacon's own words – "all operations and possibilities of operations from immortality (if it were possible) to the meanest mechanical practice."[3]

Gradually the Baconian program became associated with the totality of modern science and its infinite applications in technologies and industrial production, so that all these together were seen as a progression without natural limit towards endlessly enlarging humanity's operational capacity in the world – now, to extract and use energy from atomic nuclei, to craft materials, chemicals and machines with marvelous properties, and to manipulate the genetic structures of all biological creatures. And yet, all the while, as this operational capacity has added new and previously undreamed-of powers of creation and destruction to our repertoire, all derived from the properties of nature, one thing remained constant: The nature of the collective human agency wielding these powers. True, there is the illusion that civilizing secular institutions have grown up alongside these new powers, channeling them largely towards the manufacture of utilities and containing their destructiveness. We may disagree over our evaluation of the strength of these structures; I for one regard them as exceedingly fragile. They have been severely tested during the world wars and the Holocaust of the preceding century, as well as by the nuclear superpowers' doctrine of mutually assured destruction and the political terrorism that haunts us now. (It may be said humanity has "passed" these tests so far, in the sense that the worst outcomes imaginable did not occur, but in my view this result was not inevitable.) I will return to this theme later.

My working hypothesis in this paper is: There is a great and indeed growing disparity between the unchanging defect in human agency (Kant's "crooked timber"), represented in humanity's deep and enduring political and religious divisions, on the one hand, and the immense increase in the power of humanity's technological instruments, on the other. And this is the hidden secret and terrible contradiction, or the cruel joke, if you will, at the heart of the

modern project known as the domination of nature.[4] The contradiction referred to is the ever-widening gap between humanity's growing operational powers, on the one hand, and the enduring weakness of its collective capacity to steer (through international political institutions) those powers away from destructive applications.

Modern science asked for a free hand for its own development (including freedom from obeisance to religious dogma), a request that was granted by modern society because all presumably wanted what it promised to humanity in return, namely, an abundance of goods and liberation from helpless subjection to natural forces.[5] For those that still operate within this tradition, all that remains now for the many "still-developing" nations is to find somehow the path to "development"; no one doubts that this path leads through industrialization and the next stages of innovation expected from the sciences and the new technologies they will spawn.[6] This relentless expansion of human operational power in the world is the essence of modernity, the project that unites all the stages of historical change from Bacon's time to our own and beyond. There is an unresolved contradiction at its heart. If this contradiction itself is not posited explicitly as a task for political-institutional action, and once posited, if it is not then overcome, that project may collapse and bring about the greatest political tragedy of the modern epoch.

At each stage of science and technology the scope and scale of humanity's attained operational power over (through) nature is magnified. These powers have changed qualitatively as well as quantitatively, and now on the horizon are further qualitative changes that promise to usher us into an entirely new dimension, where both the "upside" (the benefits, especially health benefits) and the "downside" (the potentially negative outcomes) become more fateful. We are

playing a game in which the stakes – and therefore the risks – are raised continuously, and where there does not seem to be any way to leave the table and stop playing.

Catastrophic Risks.[7]

I define "catastrophic risk" as the possibility of harms to humans and other entities so great that the future viability of existing animal species, including our own, is called into question. Thus these are not only risks to the present generations of living animal species, but also to future (perhaps *all* future) generations of presently existing species. One well-known risk of this type is what has been called "nuclear winter," the threat of a pervasive environmental catastrophe that could follow a large-scale exchange of nuclear weapons between the United States and the former Soviet Union (now Russia), under the doctrine of "mutually assured destruction." The hypothesis of environmental catastrophe was based on the expectation that the earth's atmosphere would become loaded with particulate matter, blocking much of the solar radiation reaching the earth's surface, perhaps for a period of years (such an event is thought to have occurred following the impact of massive asteroids colliding with the earth).[8] In addition, of course, the huge doses of radiation emitted by these exploding weapons would have profound genetic consequences for plants and animals.

Given the existing stockpiles of nuclear weapons, the risks associated with them (including terrorism risks) still exist, although in view of the political instability in Russia it is difficult to know whether the probability now is greater or less than before. *But new catastrophic risks are on the horizon, and these have a fundamentally different character that may require very different institutional responses from us.* Their common characteristic,

considered as basic and applied science and the technological applications made possible through them, is that they are all based on our latest understanding of biological systems through molecular biology. More specifically, their common scientific basis is the capacity to characterize complete genomes and to manipulate them by means of recombinant DNA techniques (or to create DNA-like mechanical structures).

The Lords of Creation.

The ultimate goal of genomics research, already envisioned and set as a practical objective, is a knowledge of genetics so complete that living entities (and life-like mechanical entities) could be constructed, or alternatively deconstructed and then rebuilt and varied, *ab initio.* According to an article published in *Science* in 1999, researchers working with a microbial parasite sought to characterize and develop "an organism with a minimal genome, the smallest set of genes that confers survival and reproduction":[9]

> But since each of the 300 genes found to be essential could have multiple functions (pleiotropism), investigators had no way of finding the degree of redundancy and whittling the genome down further. The next logical step: make a synthetic chromosome of just those genes to build a living cell from the ground up.

Considered in their human implications, I regard these developments as giving rise to a new type of catastrophic risk, which I have called "moral risks."[10] Gradations of being (inorganic and organic matter, plants, insects, animals, humans) are and always have been a foundation-stone of humanity's ethical and religious systems. More particularly, "self-consciousness" has been regarded as the essential and distinguishing mark of a human being, uniquely; yet as illustrated in the following section we have, apparently even among some senior scientists, an inclination to experiment with "crossing" these dimensions of existence in an almost casual mood. In my opinion very great evils await us in going down that road.[11]

A Short List of "Catastrophic Risks."

1. There are risks from the use of future bio-engineered pathogens used as weapons or war or terrorism. A recent review in *Nature* listed the following possibilities[12]: (a) transferring genes for antibiotic resistance (e.g., to anthrax or plague, as Russian scientists have done) or pathogenicity (the toxin in botulinin, which could be transferred to *E. coli*), or simply mixing various traits of different pathogens, all of which is said to be "child's play" for molecular genetics today; (b) through "directed molecular evolution," especially what is called "DNA shuffling," producing "daughter genes" by shattering genes and then recombining gene fragments in ways that change the natural evolutionary pathways of bacteria; (c) creating "synthetic" pathogens, that is, "artificial" bacteria and viruses, by starting with a synthesized "minimal genome" which was capable of self-replication (a kind of empty shell), to which "desired" traits could be added at will; (d) creating hybrids of related viral strains. These possibilities multiply as scientists begin publishing the complete DNA sequences of well-known pathogens: "… [G]enomics efforts in laboratories around the world will deliver the complete sequence of more than 70 major bacterial, fungal, and parasitic pathogens of humans, animals and plants in the next year or two…."[13] Scientists working in these areas point out that actually getting engineered viruses and bacteria to survive in the environment, and to be maximally useful as weapons of war and terrorism, would not be easy to do; moreover, defenses against them can be constructed. What we are faced with the advances in molecular genetics, therefore, is an increase in the risks (possible harms) of novel agents being used in these ways for nefarious purposes.

2. There are related risks from accidental or unintended consequences of genomics research, especially from the genetic engineering of viruses and bacteria, which could result from the escape into the environment of virulent new organisms, irrespective of whether these organisms were intended originally for "beneficent" or "malevolent" purposes.

   There was a brief flurry of publicity earlier this year when Australian researchers announced that, in engineering the relatively harmless mousepox virus with a gene for the chemical interleukin 4, in an attempt to create a contraceptive vaccine for mice, they had accidentally made the virus exceptionally toxic: "The virus does not directly threaten humans. But splice the IL-4 gene into a human virus and you could create a potent weapon. Add the gene to a pig virus, say, and you could wreck a nation's food supply."[14]

3. There are risks to the "nature" of humans and other animals from intended or unintended consequences of genetic manipulations that either introduce reproducible changes into an existing genome (e.g., human or animal germ-line gene therapy), thus modifying existing species, or create entirely new variant species. For illustration here, I will confine myself to the example of "chimeras," that is, combined entities made up of parts of the genome of two or more different species, including of course humans. Some molecular biologists apparently already have done casual experiments inserting human DNA into the eggs of other animals and growing the cell mass for a week or so; and there is much speculation as to what would happen if human and chimpanzee DNA were crossed, since chimps share over 98% of human genes.[15]

4. The DNA of all species now on earth is composed of the same four chemical bases, abbreviated A, T, C, G, arranged into two pairs (A/T, C/G), that make up the "ladders" on the double helix of DNA; different combinations of the base-pairs specify one of 20 amino acids, which combine to form various proteins.[16] Some scientists are experimenting with adding more chemicals that would act as new bases, so that, for example, there would be six rather than four bases and perhaps three base-pairs. One of the scientists doing this work is Peter Schultz: "Schultz often says living things have only 20 amino acids because God rested on the seventh day. 'If He worked on Sunday,' he said, 'what would we look like?'"[17] The self-comparison between Dr. Schultz and God is interesting, to say the least.

5. There are risks to organic life, stemming from certain possibilities inherent in the development of robotics and nanotechnology, were publicized in a now-infamous paper (April 2000) by Bill Joy, Chief Scientist at Sun Microsystems and creator of the "Java" script. Joy wrote:

> The 21st-century technologies – genetics, nanotechnology, and robotics (GNR) – are so powerful that they can spawn whole new classes of accidents and abuses. Most dangerously, for the first time, these accidents and abuses are widely within the reach of individuals or small groups…. I think it is no exaggeration to say that we are on the cusp of the further perfection of extreme evil, an evil whose possibility spreads well beyond that which weapons of mass destruction bequeathed to the nation-states, on to a surprising and terrible empowerment of extreme individuals.[18]

The link between nanotechnology and biotechnology is fascinating: Although the former works with intrinsically inert materials, it is seeking to turn them into a perfect analogue

of a biological (self-assembling) system. One of the leading Canadian scientists in this field, Dragon Petrovic, has explained the quest as follows:

> In the future, he predicts, technicians will teach individual molecules and atoms to assemble themselves into wires and sheets of impeccable purity and thinness…. [Imagine] instruments made of compounds that are self-assembled, atom by perfect atom – materials so pure that they could never snap apart or break under normal conditions…. "Imagine [Petrovic says] the linkage to telecom – can we get DNA molecules to self-assemble into perfect sheets and wires only an atom thick, and then send electrons and photons to stimulate the DNA to do things – start growing; stop growing; assemble into certain geometric shapes? It's analogous to what a structure like bone does in nature, where the brain is the electronic device and the nervous system transmits the information."[19]

Bill Joy's essay already had explored the dark side possibly inherent in the quest for self-replicating nanotechnology machines; the internal quotation in the passage by Joy below is from a book by Eric Drexler, *Engines of Creation*:[20]

> An immediate consequence of the Faustian bargain in obtaining the great power of nanotechnology is that we run a grave risk – the risk that we might destroy the biosphere on which all life depends. As Drexler explains:
>
> > Tough omnivorous "bacteria" [created by nanotechnology] could out-compete real bacteria: They could spread like blowing pollen, replicate swiftly, and reduce the biosphere to dust in a matter of days…. Among the congnoscenti of nanotechnology, this threat has become known as the "gray goo problem." Though masses of uncontrolled replicators need not be gray or gooey, the term "gray goo" emphasizes that replicators able to obliterate life might be less inspiring that a single species of crabgrass. They might be superior in an evolutionary sense, but this need not make them valuable.
>
> Joy ends his essay with a plea for the urgent need to begin thinking about how to contain these risks. We will need, he thinks, a rigorous regime to oversee the technology's development and require that certain applications be relinquished; "enforcing relinquishment," he says, "will require a verification regime similar to that for biological weapons, but on an unprecedented scale."

One important point must be emphasized here, namely, that what has been just described are (hypothetical) catastrophic "downside *risks*," that is, the potential for very great harms to be done through some future technologies that are already on the drawing-boards. For each of these developments there are both "upside benefits," resulting from future applications of these technologies that could bring substantial benefits to us, as well as the potential for "protective" technological innovations that could mitigate, offset, reduce, or even eliminate at least some of the downside risks. To take the example of the engineering of viruses as bioweapons: As a counter to this threat (and also just to reduce the debilitating effects of viral infections on population health), research is under way in molecular genetics to develop new antiviral drugs that can block the infectious action of any viruses at the cellular level (preventing receptor binding, cell penetration, replication, production of viral proteins, and so on).[21] Considered as a totality, however, what these conjoined prospects do is to continually "raise the stakes" in our technological game with nature, whereby the new sets of risks and benefits reflect both, and simultaneously, the potential for an upside of hitherto unattainable benefits and a downside of hitherto unimaginable horrors. As discussed in a later section, this entire prospect increases the challenge to our social institutions to manage our technological prowess so as to realize the benefits and avoid the harms, and likewise increases the risk that we will be unable to do so.

What is different today?

There are undoubtedly other types of catastrophic risks, but those introduced above are sufficient for purposes of discussion![22] My main point is that these newer risks are fundamentally different in character from the case of nuclear winter, and the difference has to do with the distribution of knowledge and technological capacity relevant to them (thus requiring a very different

institutional response). The technologies giving rise to the nuclear winter risk are controlled by just two nation-states and are maintained (for the most part, and until now) under a thick blanket of military security and secrecy, although the smuggling of nuclear materials out of the former Soviet Union is cause for worry. Both the essential theoretical knowledge, and the engineering capacity needed to turn that into weapons, is confined to a relatively small circle of experts and officials. Not so with the new technologies, as Bill Joy emphasized strongly in his remarkable essay.

The catastrophic risk areas listed above stem from current research programs that are widely distributed around the world; moreover, the strongest drivers of them are private corporations, including the large pharmaceutical multi-nationals, acting with full encouragement, support, and incentives from national governments. Especially where the possible health benefits of genetic manipulations are concerned, the combined public-private interests are overwhelmingly supportive, driving the research ahead at an accelerating pace. Governments especially are enthralled with the economic significance of these new technologies, are competing with each other under innovation agendas to capture major shares of the corporate investments, and are loathe to stop and think about unintended consequences.

All of the characteristics of the knowledge and applications in these areas mean that it is extremely difficult even to think about controlling either the process or the results. For one thing, the knowledge is widely distributed among individual scientists; for another, it is widely distributed among private actors (corporations) which have the option of moving their operations on a regular basis, seeking perhaps the least-regulatory-intensive national base on the globe.

(Might we expect H. G. Wells' *The Island of Doctor Moreau* to be replicated many times?[23]) Third, the technologies themselves become increasingly "simplified" and thus easier to hide, if necessary; the genetics technologies, for example, can be carried out in small laboratories almost anywhere.

Fourth, oversight is inhibited by the lure of truly extraordinary economic and health benefits promised by the new knowledge and technologies. And fifth, just the astonishing pace of innovation itself today makes the prospect of control and regulation a challenge.

During the past year national governments have been scrambling to respond to just a few of the dimensions of these new risks. Most attention has been focused on human cloning, where a few rogue scientists have challenged authorities in various jurisdictions to "try to stop us," and laws prohibiting this technology are being passed rapidly. But this is a relatively crude technology, albeit one which excites public attention, and one wonders whether authorities will become complacent about their ability to control unacceptable technologies due to their experience with this case. (Meanwhile, there are increasing reports that many genetics scientists are "going underground," in the sense that they have stopped talking publicly about their research in progress for fear that public reactions will be hostile and will result in official steps to halt it.)

Among the scientists cited in this paper, two (Bill Joy and Ian Ramshaw) have called for urgent action under the Biological and Toxic Weapons Convention (1975), to provide explicitly for a global oversight effort over some of the new technologies and their applications described

earlier.[24] Unfortunately, we know international negotiation to be at the best of times a tedious and protracted process, and there is reason to believe that in this domain it could be fractious and unsuccessful. This is because all of the technologies described represent frontiers of industrial innovation in which great multinational corporations and the national governments which protect their interests (especially the United States) have significant investments; both corporations and governments would be loathe to see those investments and the immense payoffs expected from them jeopardized by an international control regime. A recent article co-authored by a molecular geneticist and a specialist in the international convention on biological weapons has called for an urgent new effort to strengthen verification under the 1975 Convention and to enlist the biomedical research community in an effort to strengthen deterrence against the uses of bio-engineered organisms for war and terrorism.[25]

"Eppur si muove" ("And yet it moves!")

Recently the sociologists Reiner Grundmann and Nico Stehr posed "the question of social surveillance and regulation of knowledge," suggesting that "knowledge policy" may include "the aim of limiting, directing into certain paths, or forbidding the application and further development of knowledge."[26] If scientific knowledge is included here, as I assume it is, this proposition will not be well received. One of the great founding faiths of modern society is that infinite benefits flow from the act of liberating the natural sciences from the intellectual and institutional shackles of dogma, including religion; its inspirational image is that of Galileo before the Inquisition, forced to recant publicly his belief about earth's movement in space, but unyielding in his mind and certain subjectively of his ultimate vindication.[27] Anyone who seeks to challenge this faith is in for a rough ride; nevertheless, it may be our duty to do so now.

Modern society gradually freed the development of knowledge, including the sciences of nature, from direct and ongoing oversight by other social institutions, notably religion. In effect it created autonomous, self-governing disciplines of knowledge, which evolved their own mechanisms (such as peer review) to guard against corruption through dogma and privilege and, more importantly, to guarantee an open-ended progression of new findings, where even fundamental doctrines could be challenged and superseded. This was a remarkable achievement. The new sciences repaid their debt to society by delivering an endless stream of technological innovation as the foundations of industrial and economic development. However, every stage of development, no matter how it differed in conceptual structure from its predecessors, was unified by a common accomplishment, namely, the increase in the potential scope of humanity's operational power in the world beyond anything heretofore imaginable.

But the societal context did not change fundamentally – at least, it did not change to the extent that was hoped-for in the original scheme.[28] One may visualize the outcome as two forces joined together by – and pulling on opposites ends of – a powerful elastic band, where the tension on the band increases steadily. On the one side are the sciences and technologies, developing autonomously and granting ever-increasing operational powers to human agents; on the other, the social institutions which channel human activities to collective ends. The growth in operational powers increases the tension, and thus requires a matching response, through the channeling capabilities of institutions, in terms of managing those powers responsibly. Inasmuch as some balance in the evolution of capabilities on the opposing sides is maintained, it is a "productive" tension, delivering enormous benefits for human well-being. But the downside risk

grows in proportion to the increasing tension on the band. In the twentieth century humanity had not one but two narrow escapes from the unleashing of the full destructiveness of this potential, first in the Nazi assault on the entire fabric of social institutions themselves, later in the precarious balance of nuclear terror between the United States and Russia. Now technology's advance is promoted through a globalized economy, in a context where the international institutions through which national divisions are mediated remain pathetically inadequate – and, indeed, viewed as illegitimate by many in the world, including many citizens of the world's last superpower.

One response to the foregoing is as follows. Accepting just for the sake of argument that this perspective is valid, it could be said, the answer is ridiculously simple: Strengthen the social institutions to the required degree, so that the enrichment of their capability to contain destructive forces matches the corresponding steady increase in operational power. Indeed, one wishes it were so simple. One slight difficulty with this cheerful scenario is that there are many in the world who already have ready access to a lot of those operational powers in their destructive forms, who reject root and branch the legitimacy of secular social institutions founded on what we call "Enlightenment" values. Once again, as it was in the distant past, the human world seems to be eerily at ease with the language of apocalyptic visions. During the Black Death vulnerability to the vagaries of nature and chance (aided by human commerce) yielded enough victims to signal for many the end of days. Today we have reason to fear that those who invented in remote caves the devilish mixture of science and religious martyrdom might intentionally sow similar epidemics among us, using the most advanced techniques of

molecular biology to engineer infectious agents for maximum lethality. This is a strange sort of progress indeed.

Are there forms of knowledge about nature (including a technological capacity to manipulate nature based on them), now envisioned as practical possibilities in foreseeable futures, of which it may be said that they are too dangerous for humanity to possess? Too dangerous, at least, in the hands of that radically imperfect humanity in and around us, including its all-too-delicate veneer of civilization, which now seems prepared to seek that knowledge? And if so, is it even conceivable that one could argue for their suppression on the grounds that, once realized they will inevitably be deployed, to ends so evil, running unhindered into the future, as to destroy the moral basis of civilization?[29]

Such questions are being raised by some in the academic community, especially with reference to biotechnology. An editorial earlier this year in *New Scientist*, commenting on the inadvertent laboratory creation of a virulent engineered virus which could be used as a weapon in biological warfare (discussed above on page 8), said:

> There's also the problem that many biologists choose to ignore biotechnology's threats…. John Steinbruner of the University of Maryland, College Park, has suggested setting up bodies to oversee areas of biological research. Such bodies could question or even stop research, or decide if results should be published. As Steinbruner is well aware, his proposal strikes at the heart of scientific openness and freedom. But leaving things as they are is not an option. Biotechnology is beginning to show an evil grin. Unless we wipe that smile from its face, we'll live to regret it.[30]

As a practical matter, therefore, we may be able to confront the issues raised in this paper in terms of autonomous self-regulation and self-policing within the enterprise of scientific knowledge itself. Certainly it is unthinkable to confront these issues without the active support

and collaboration of working scientists and their professional organizations. Those of us who work on the public policy side of things will have to see whether leading scientists can be engaged in discussions about the following types of questions:

1. Can we characterize a set of new catastrophic risks, as defined here, related to the leading-edge technologies that are being developed?
2. Do these new risks have an essential character that will make them difficult to control, because the knowledge and the technologies will be so widely diffused?
3. Can these risks be confined to acceptable dimensions by the institutional means now at our disposal, including international conventions on prohibitions? If not, what new tools do we need, and how can we get them?
4. Do professional associations of scientists working in these fields have special responsibilities to assist societies in controlling these risks, and if so, are those responsibilities now being discharged adequately?[31]

Conclusion.

If I may be permitted some metaphorical liberties here: The project known as the domination of nature appears to have been a game played with the Devil, a Faustian bargain wherein humanity received vast new powers in exchange for a promise to replace religion as overseer of society with other institutions that would unify humanity under the banner of a thoroughly secular science of nature.[32] The problem is, the game goes on, we are not allowed to take our winnings and quit, and our opponent keeps pouring whiskey and raising the stakes as each hand is dealt!

What is at risk in this game, now, is the possibility that the tension between science and society will become both unmanageable for institutions and unbearable for individuals, in other words, that the destructive applications of our operational power finally will overwhelm the rest. To reduce the probability of this coming to pass it is necessary first to get agreement among influential social actors that this *is,* as described here, a momentous challenge which contemporary society cannot avoid. The first practical test of our resolve in this regard, I believe, is whether influential scientists can be mobilized in the cause, scientists who will reaffirm the need for new oversight structures, to be erected both within the practice of science itself and also in the relation between science and society. Hegel made a remark, I believe, somewhere in his writings, to the effect that only the hand which inflicts a wound can heal it. The wound here is the rupture with the dominant pre-modern relation of humanity and nature, governed by value-laden categories of being, and its replacement by modern science's purely operational orientation to the totality of the natural world. I do not speculate here on what a healing of that rupture could mean now, at least, not in any "ontological" sense. But in a practical sense, as a matter of public policy, I think it is clear what is required – namely, that the practitioners of science join others in a program to try to bring our operational powers under the control and direction of social institutions that have universal validity, ones that correspond in sufficient measure with the common aspirations of humanity. It is my contention that today's dominant institutions do not have such validity and that, as a result, everyone on earth is at risk of having these powers become instruments in an Armageddon waged to the bitter end by contending social, ethnic, national, and religious interests.

What remains to be seen is whether the task as defined here can be widely recognized and grasped as such, while there is still time, and whether our scientific enterprise can be steered towards the shelter of a social compact having universal validity.[33] If it turns out that despite our best efforts this cannot be done, there will arise a set of other questions that, for now at least, are too abhorrent for many even to consider. These questions have to do with the possibility that, taking both "normal" human passions and human institutional failings into consideration, there may be forms of knowledge that, as a practical matter, are too dangerous for us to possess, and that our only choice is to renounce and suppress such knowledge or suffer the consequences. In mentioning them we go to the heart of the fateful compact between science and society that has set the course for the development of modern society from the seventeenth century onwards, under the program known as the domination of nature. It is likely that contemporary society is not ready to deal with them, at least, not yet.

Endnotes.

[1] New York: George Braziller, Inc., 1972; paperback edition, Boston: Beacon Press, 1974. Reprinted with a new Preface in 1994, Montreal: McGill-Queen's University Press (still in print).

[2] This paper was first delivered, under the title "The Domination of Nature: Modernity's Greatest Political Tragdy?" at the symposium, "Critical Theory of Technology and Nature," Institut für Philosophie, Technische Universität Darmstadt, Darmstadt, Germany, October 24-26, 2001 (organized by Dr. Gernot Böhme).

[3] *The Domination of Nature*, chapter 3; the quotation is on p. 54 (1994 edn.). Of course one reads frequently now about the experiments of molecular biologists who are seeking to create an "immortal" cell and to manipulate the genes that control the process of aging in all biological entities.

[4] The endurance of the religious component in these divisions is inconsistent with the Enlightenment perspective on human progress (especially its belief in the institutional hegemony of the secular state) which became an integral part of the ideology of the domination of nature. The apocalyptic element in religion, in its relation to the immense increase in technological power during the modern period, is an especially troublesome aspect of the contradiction carried in this ideology.

[5] The historical trajectory of modernity, cast in terms of Hegel's philosophy of history, looks like this (see *The Domination of Nature,* pp. xxi-xxvi for a fuller version): Modern society "showed" itself to historical actors beginning in the eighteenth century as a struggle to create a new form of economy, or relation between economy and society, that would be capable of satisfying human wants far better than all earlier societies had (that is, it was understood by them in these terms). The rise of socialism in the nineteenth century opened a contest over the means whereby this goal could be achieved – but the goal itself was shared by both sides. That contest (in the form of class struggle) is now exhausted, and only the goal remains, unfulfilled for most but fervently desired by huge numbers among the world's population. At the same time, operating "behind the backs" of these historical actors, and through their shared mission to create an economy based on systematically exploiting natural resources for the production of abundant goods, the "cunning of reason" created the scientific-technological-industrial apparatus that now dominates our lives and expectations.

[6] One indication that this expansion of operational power is an essential (rather than accidental) feature of modernity is that it contains a relentless internal dynamism that impels it forward: Each stage of accomplishment is simply the platform for the next adventure. An example is provided by the new type of genetic manipulation of food crops in agricultural biotechnology, which, its advocates claim, provides the only hope we have of supplying adequate nutrition for the billions of undernourished people in the world. Yet this was what the previous technology, known as the "Green Revolution," had promised to do. What the Green Revolution did in fact was to create the conditions under which greater numbers of undernourished people could be

produced, thereby necessitating a further technological "solution" marked by greater operational power.

[7] Some of the following sections were first presented at the conference, "The Governance of Knowledge or Knowledge Politics," Kulturwissenschaftliches Institut, Essen, Germany (September 5-7, 2001), organized by Dr. Nico Stehr.

[8] On asteroid risk: http://impact.arc.nasa.gov/ : "Statistically, the greatest danger is from an NEO [Near-Earth-Object] with about 1 million megatons energy (roughly 2 km in diameter). On average, one of these collides with the Earth once or twice per million years, producing a global catastrophe that would kill a substantial (but unknown) fraction of the Earth's human population. Reduced to personal terms, this means that you have about one chance in 20,000 of dying as a result of a collision."

[9] *The Scientist* 14[1]: 12, Jan. 10, 2000 (http://www.the-scientist.com/yr2000/jan/multiple_p12_000110.html)

[10] "We encounter a state of moral risk when we pose certain options for ourselves, as goals which might be realized by using science to manipulate nature, that imply fundamental changes in the 'order of being' as it has been experienced by humans until now." William Leiss, *In the Chamber of Risks: Understanding Risk Controversies* (Montreal: McGill-Queen's University Press, 2001), Chapter 11, "Into the Maze of Moral Risks," p. 267.

[11] See generally *ibid*., pp. 259-68, where Mary Shelley's great novel, *Frankenstein* (1816), provides the basis for discussion.

[12] Carina Dennis, "The Bugs of War," *Nature*, vol. 114 (17 May 2001), pp. 232-5.

[13] C. M. Fraser and M. R. Dando, "Genomics and future biological weapons: the need for preventive action by the biomedical community," *Nature Genetics*, advance online publication, 22 October 2001, p. 2 (http://nature.com.anthrax) .

[14] *New Scientist*, 13 January 2001 (http://www.newscientist.com/editorial/_22731.html). "Ian Ramshaw, a member of the Australian team, says [no one] could have foreseen that the altered virus would kill even vaccinated mice." The researchers were so alarmed by what they had inadvertently done that they first notified the Ministry of National Defense, then waited two years before publicly announcing and publishing their experiment, simultaneously calling for modifications to the international convention on biological warfare to include devices of this type. The original story is in *New Scientist*, 10 January 2001 (http://www.newscientist.com/news/news.jsp?id=ns9999311)

[15] Scott Foster, "Man-beast hybrid beyond talking stage," *The National Post* (Toronto, Canada), 22 August 2001, p. A16. "Last October, Greenpeace Germany dug up a patent claim for a human-animal hybrid, … U.S.-based Biotransplant and Australia-based Stem Cell Sciences grew a pig-human embryo to 32 cells before ending its life."

[16] On DNA see the superb graphics and animation at: http://vector.cshl.org/dnaftb/

[17] Andrew Pollack, "Not Life as we know it," *The National Post* (Toronto, Canada), 26 July 2001, p. A15 (reprinted from *The New York Times*).

[18] Bill Joy, "Why the future doesn't need us," *Wired Magazine* (http://www.wired.com/wired/archive/8.04joy_pr.html)

[19] Allen Abel, "The God of Small Things," *Saturday Night Magazine* (*The National Post,* Toronto, Canada), 21 & 28 July 2001, pp. 34-37.

[20] Eric Drexler, *Engines of Creation: The Coming Era of Nanotechnology* (New York: Anchor Books, 1986), available in its entirety at: http://www.foresight.org/EOC/

[21] William A. Haseltine, "Genetic Traps for Viruses," *Scientific American*, November 2001, pp. 56-63.

[22] Another potentially catastrophic man-made risk was the possibility that the Relativistic Heavy Ion Collider at the U. S. Brookhaven National Laboratory could accidentally produce a new form of matter, called a "strangelet" (composed of quarks). Some speculated that, if such a particle were to be created with a negative charge, it could proceed to "consume" our entire planet in short order (just as if what we happen if we encountered a black hole). At the request of Laboratory officials, this possibility was debated by a panel of senior physicists who concluded that the Collider could not produce such a particle. An introduction to this intriguing discussion can be found in a short article, "Apocalypse Deferred," in the December 1999 issue of *Scientific American*: www.sciam.com/1999/1299issue/1299scicit3.html

[23] First published in 1896, available online at: http://www.bartleby.com/1001/0.html

[24] http://www.brad.ac.uk/acad/sbtwc/ In July 2001 the United States created great consternation among the signatories by refusing to ratify an implementation (inspection) protocol, thus rending the convention largely impotent, because of concerns that the security of the intellectual property being developed by its private-sector biotechnology firms might be compromised: http://www.brad.ac.uk/acad/sbtwc/evaluation/evalu22.pdf

[25] Fraser and Dando, *op. cit.* (note 13), p. 4.

[26] "Policing Knowledge: A New Political Field," background paper for the conference, "The Governance of Knowledge or Knowledge Politics," above note 7.

[27] Galileo Galilei (1564-1642): http://www.rit.edu/~flwstv/galileo.html

[28] Bacon's famous utopia, "The New Atlantis," presents the scientific establishment as controlling force in society as a whole, acting as guarantor for the appropriate use of technological innovation: See *The Domination of Nature,* pp. 61-71 (1994 edn.).

[29] There is a practical argument to the effect that, since the development and deployment of such knowledge cannot be thwarted, the most prudent course of action is to superintend its progress closely, so that technological antidotes to the potentially most frightful and destructive applications will be ready before they are needed. I regard this as a strong and possibly definitive counter-position to the one posed here in the serious of rhetorical questions.

[30] *New Scientist*, 13 January 2001 (http://www.newscientist.com/editorial/_22731.html).

[31] The 1975 Asilomar Conference that established some early ground-rules for DNA research at the initiative of the scientific community itself had a 25th-anniversary meeting in 2000. At least according to one report, some senior scientists today are doubtful that the "Asilomar model" will prove to be useful in the future for the oversight of problematic applications of DNA research, particularly because of the enormous pressure of the commercial interests that has developed in the meantime. See *The Scientist* 14[7]: 15, 3 April 2000 (http://www.the-scientist.com/yr2000/apr/russo_p15_000403.html)

[32] Although we are dealing in metaphors here, this is the literal meaning of the passage from Bacon cited as the epigraph for this paper.

[33] There is not time here to develop this concept adequately. Here it must suffice to say that "universal validity" is not an absolute, in the sense that every person must "buy in," but rather is some common orientation that can attract and hold the support of the most influential and enduring cultural traditions around the world.