"Embracing Risk, Manipulating Chance: Will it all End Well?"

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From the Domination of Nature to Risk.

My doctoral thesis in philosophy at the University of California, San Diego, completed in 1969, was the last act of my decade-long apprenticeship with Herbert Marcuse. It later became my first book, entitled *The Domination of Nature* (first published in 1972, and, I am pleased to say, still today in print). At the end of my thesis oral, my supervisor announced that I was being awarded my degree for the single sentence that concluded the thesis, where I had reversed a famous Hegelian maxim, "the cunning of reason."

[Hegel was fond of metaphors, and my favorite is, "The Owl of Minerva takes flight at dusk." What he meant was, we can only truly understand a historical epoch after it is over, when the life has gone out of it.]

Using a history-of-ideas approach, to which I had been introduced at the graduate program of that name at Brandeis University, I traced the development of the idea that humanity seeks to master or "conquer" nature through the progress of the modern sciences of nature and its technological applications. Arising in the Renaissance, this idea was given its definitive formulation in the writings of Francis Bacon during the first quarter of the seventeenth century.

The eighteenth-century French Enlightenment thinkers took further Bacon's inspired vision, as expressed best in Condorcet's masterpiece, *Sketch for a Historical Picture of the Progress of the Human Spirit* (1795), a profound humanist tract written while its author was in hiding from the Terror. Condorcet, himself both a great mathematician and a social progressive, and a colleague of Lavoisier, the "father of chemistry," recognized the import of the natural sciences in promising an end to grinding poverty through economic progress; but he also championed the role of the sciences in dispelling the hold of ignorance and superstition over the human mind, through which regressive social practices and institutions were maintained. Condorcet saw the internal connection between the applications of what we would today call "evidence-based reasoning" in both a mastery over the powers of external nature and a growing self-mastery over human social behaviors.

With the help of an extraordinarily perceptive one-liner written by Walter Benjamin, about the need to achieve mastery over the mastery of nature, I identified a potential internal contradiction in this grand historical adventure. For the species which seeks to master "external" nature – the physical environment, its resources and "powers" – has failed miserably so far to achieve self-mastery of its own nature.

The mastery over external nature takes the form of discovering an endless series of new powers and characteristics within nature that are turned through technologies into potent new capacities for action in the world. These new technological powers are placed at the service of a species still riven by atavistic hatreds and ancient superstitions, where the rivalries among national and social groupings threaten to break out into unrestrained mayhem at any time. If you will allow me to refer to just a single image to

illustrate what I mean, think of the nation of Iran, the locus of one of the oldest continuous stories in human civilization, whose President rehearses apocalyptic religious fantasies in his speeches before the United Nations, while back in his homeland, in thousands of highly-sophisticated spinning centrifuges, hidden deep underground, uranium oxide is being enriched so that either nuclear energy plants, or nuclear bombs, or both, can be supplied. Lest I be misunderstood here, I hasten to add that the Iranian mullahs have no monopoly on this juxtaposition of scientific modernism and atavistic motivation.

In his phrase the cunning of reason, Hegel alluded to the notion that the impulse of rationalism can work "behind the backs" of historical actors, bringing into being forms of progressive thought through a developmental process of which those actors would remain blissfully unaware. In my reversal, looking at mastery of nature through the lens of "the cunning of unreason," I imagined that the hidden drivers of history might work in the opposite direction as well, supplying irrationalistic impulses with the requisite means to pursue truly cataclysmic destructive goals using the products of rationalism's glory, modern science and technology. The point was not lost on the philosopher whose closest colleagues had produced the work entitled *Dialectic of Enlightenment* (see further Leiss 2011).

As for my own perspective, I regard the spirit of "enlightenment," along with the modern natural sciences through which it is enabled, as *the* defining characteristic of modernity. And I believe that the fate of both – Enlightenment and modernity – hangs in the balance today. But I will not pursue this theme further here; if it interests you, you might take a look at a book of mine entitled *The Priesthood of Science*.

Instead I want to focus now on the story of risk, and try to demonstrate to you that it is the same story under a different name. In a nutshell, risk management is the applied version of the mastery of nature. It is the practical dimension of the great adventure I have referred to, the attempt to increase human welfare by, first, understanding how nature "works," and then, using technologies to change the odds in our favor with respect to the contest of our species with natural forces.

Embracing Risk, Controlling Chance.

Risk – simply put, the chance of harm – is everywhere. For every moment of existence, for every individual, family, community, nation, and for the world as a whole, the chance that some type of harm might strike unexpectedly is ever-present. One-third of all first heart attacks are fatal and occur with no prior warning; global financial catastrophe appeared without warning, like a mighty flash of lightning, in mid-September 2008; and on average once every hundred-million years during our planet's history, a massive asteroid, arriving seemingly out of nowhere, has wreaked havoc on our planet.

There is an almost infinite array of diverse types of harms. This has always been true. What is relatively new is describing the imminence of potential harm as a "risk." To call something a risk means that we understand the threat in a quite specific way, namely, as a source of potential harm that is (except in relatively few cases) which is *potentially* controllable by our conscious acts. So the understanding of our environment as a source of multitudinous risks is not, as some believe, an expression of a pervasive, debilitating fear and unease about existence (Beck 1992). The truth is exactly the opposite: A risk-based understanding of the world implies, not a dread of

uncontrollable forces but rather a confidence that a much higher proportion of our life-outcomes is amenable to rational control than was ever the case in the past.

For example, for women in pre-modern times pregnancy and childbirth were usually the leading causes of premature mortality (women then experienced in addition, with all others of their species, the additional scourges of accidents, rape, famine, disease, war, violence, plunder and dozens of other calamities). All of them were experienced as simple fate and happenstance, to be endured and outlasted if possible but not to be avoided. Explanations for them were most commonly found in the deeds of supernatural entities – spirits, benevolent or otherwise – acting directly upon events or using human agents as their surrogates. [How very far we have advanced since then! If only we could figure out whether God really intends rape to be a good opportunity for creating human life on earth.]

The systematic idea that harms have causes rooted in the characteristics of natural and social systems, and that no supernatural entities are complicit in them, is the product of the Enlightenment of the modern West. From its earliest beginnings this "simple" idea was both a theory (seeking confirmation through experimental evidence) and a program of action (seeking changes to existing practices and institutions). Harms with natural causes, such as diseases, would be amenable to reduction through the discoveries of the new sciences of nature, first chemistry and later physics and biology. Harms with social causes, such as criminality or the gross injustices of the legal and penal systems, would be amenable to reduction through reforms to political institutions and improved insight into the determinants of human behaviors.

The champions of the eighteenth-century French Enlightenment, building on the passions of their revered predecessor, the English Lord Chancellor Francis Bacon, sought to replace fate with a chain of causation that was open to rational analysis and the gathering of evidence. Changing the prior conditions would alter the ultimate outcomes in predictable ways for the "betterment of the human condition."

So the first radical idea in the new natural philosophy was to see life-outcomes as resulting neither from unalterable fate nor the intervention of supernatural agents, but rather from conditions that could be understood and potentially manipulated to our benefit. The second radical insight was to see that, collectively, such outcomes were distributed across a range of specific end-points (such as average age of mortality in a population) which could be represented as probabilities.

The second was at least as important as the first, because it meant that one could take a strategic approach to the matter even if the pattern of outcomes itself could not be influenced. The best example is insurance, and indeed commercial marine insurance was one of the first applications of the risk-based approach (see generally Bernstein 1996). Following a risk-sharing strategy, and accumulating enough reliable evidence about the chance of a ship's cargo being lost at sea from a variety of causes, such as bad weather or piracy, meant being able to set appropriate levels of premiums for insured losses. Assembling accurate national mortality tables meant that Scottish churches could determine the premiums needed to establish the necessary financial reserves for providing family support to the widows of ministers – which is why there exists, still today, a life-insurance company in the UK with the name "Scottish Widows." And a momentous breakthrough known as "Bayes' Rule" (after an eighteenth-century English

clergyman and mathematician), showed how to deal with the uncertainties that bedevil risk: in the face of inadequate knowledge, take a guess about what is the case, and then ask yourself what evidence you could look for that would increase the likelihood of your being right about it, and keep repeating the exercise to increase your confidence level in the result.

These straightforward examples from the early modern period illustrate the simple truth that the risk-based approach represents not an exacerbation of existential fear but rather the rational hope that either the nature of the outcomes themselves, or just their consequences (that is, losses of various kinds), or both, can be controlled to some extent. In almost all cases the objective of risk management is not to abolish the sources of harms but to limit the adverse consequences our exposure to them, especially to help us to avoid catastrophic losses, that is, losses so great that it is difficult or impossible for us to recover from the encounter and rebuild our fortunes.

Being able to represent a type of harm accurately as a risk, therefore, means knowing how to manage our encounter with it in such a way that losses are minimized and gains are maximized. According to a well-known aphorism, we can only manage something if we can measure it, because we only know if our management is successful by examining the results we get for our expenditure of time and resources. The metamorphosis of harm into risk – for risk is measurable harm – is the key step in our ability to take control of important aspects of our continuous encounter with our environment, including our genetic inheritance, rather than to submit meekly to fate and chance.

Paradoxically, the steady growth of scientific knowledge about natural and social systems magnifies the number of risks we face, because it turns mysterious harms into known risks. This is a simple function of having an increasingly sophisticated and precise picture of underlying cause-and-effect relations and also of developing advanced technological tools for risk control, which inevitably introduce new risks of their own. The overriding idea is that the substitution of risks for harms will yield very substantial net benefits – in terms of longevity, better mental and physical health throughout life (with all of the associated benefits that good health brings), less pain and suffering, and the capacity to recover well from serious adverse events.

Thus the modern world is indeed riskier than was the past: But the right conclusion to draw from this truth is that this greater riskiness is a good thing, because it follows that the scope of our *potential* control options over life-outcomes has been enlarged.

I emphasize the word "potential" because both harms and risks are tricky in nature and the cause-effect relations underlying them can be subtle and hard to detect. The long latency of some diseases, such as smoking-related lung cancer, and the even longer timelines of environmental risks, especially climate change, allows us to deny the potential for substantial harm, if we are so inclined to do. Moreover, we are always exposed simultaneously to many different types of potentially harmful agents, and sorting out the dominant causative factors is onerous. As a result, risk management is almost always a difficult business and requires the application of a methodical and highly-disciplined analytical paradigm.

Essentials of the Risk Management Paradigm.

Risk management, simply stated, is the attempt to anticipate and prevent or mitigate harms that may be avoidable. Its essential steps are *foresight* (using risk estimation), *precaution* (spending some money in advance, such as purchasing insurance), and *prudence* (seeking to avoid, not all losses, but catastrophic losses, that is, being wiped out, from which future recovery is difficult and sometimes impossible). Since risk management is also, by definition, *decision-making under uncertainty*, when we take precautionary steps we cannot know whether we are wasting our money – but at least we can be reasonably certain that we have protected ourselves from catastrophic loss.

Thus, for example, we have an insurance scheme to protect people from losing most or all of their money in case their own bank fails, something that did not exist in the early 1930s, when many people lost all their savings, reducing consumption and helping to sink the economy into the Great Depression. It costs society remarkably little to maintain such a scheme.

All risk management costs money, either because some opportunities for individual gain must be renounced or because corrective risk control measures (such as regulations) demand new expenditures, or both. Thus risk management initiatives usually encounter determined resistance from entrenched economic interests, and attacks on the scientific and statistical calculations supporting a newly-measured risk are commonplace. From resistance to the earliest regulatory measures in food safety and workplace hazards, over a century ago, to the fifty-year battle waged by the tobacco industry against the epidemiology of smoking-related diseases, to today's fierce opposition to effective regulatory control over systemic financial risk by the banking

industry, to the sowing of doubt about climate science, any major initiative in risk control can expect opposition from powerful interest groups.

Nevertheless the general reach of risk management in modern society expands steadily. Both professional risk managers and ordinary citizens have ready access to information and analytical tools that, when properly deployed, allow them to modulate their exposure to harms and to incur reasonable costs to achieve targeted levels of risk control. There are literally hundreds of cases where reliable information exists, easily-accessible, that you can use to improve your chances for yourself and your children – because something like 75% of our lifetime health outcomes are dependent, at least in part, on the "lifestyle" choices we make in terms of such risk factors as diet, exercise, alcohol and drug intake, and so on.

Yet here we come to the first in a series of paradoxes in risk management; this one I call the paradox of too much information. Let me give you a couple of examples, the first from the area of blood safety. Relevant information includes the risk estimate in Canada, at present, for the chance that one person will be infected with HIV, in any year, from a unit of donated blood. The answer: 1 in 8 million donations (ten years of donations). The bottom line is, since almost certainly blood has never been safer than it is now, don't worry about it. But if you insist on more information, I could tell you that, at the 95% confidence level, the uncertainty range varies from 1 in 3 million to 1 in 20 million (Leiss et al. 2008, Appendix: What is Risk Estimation?). You ask: What does that mean? The answer is, technically, that we are a lot more confident that the risk is somewhere between those two outer bounds, than we are that it is exactly 1 in 8 million.

Then you might conclude, "Well, that says to me that you don't really know what the risk is, right? So, I'll make up my own mind."

Or take the case of the HPV [human pappilomavirus] vaccine, which can prevent cervical cancer for women. You can take your advice from the CDC in Atlanta, which will tell you that the vaccine itself is "safe." Does this mean that there are no side effects? No, but the bottom line is, "don't worry about it." Or you can go on the Internet, and find a huge stash of anecdotal evidence, including many pictures and videos, about individual (alleged) cases of serious adverse reactions, including paralysis and death. What would you like to believe? Have you heard of "confirmation bias," an area of research where it has been shown that many people structure their information search in order to find support for their prior belief? [See the PBS *Frontline* program, "The Vaccine War," broadcast April 27, 2010.]

Here's another paradox. Our increasing sophistication about risk control induces in some players a propensity to deliberately seek higher levels of risk. Some people who know that ABS systems in their cars increase driving safety tend to drive faster. Practitioners of "extreme sports" react to safety enhancements in equipment and techniques by pursuing exotic alternatives, such as skiing out of bounds at resorts where the ski runs have been evaluated by professionals. Undersea drilling for hydrocarbons extends into far deeper waters and more fragile environments, such as the Arctic, where existing safety protocols may not necessarily remain robust. And bankers deploy arcane mathematical models in order to make large bets on novel financial instruments that test the limits of their own capacity to avoid so-called "tail risk" where catastrophic losses lurk.

Risk-taking feeds on itself: The very same reasoning that once turned unknown levels of harm into calculable levels of risk threatens to flip back again into its prior state. In the Fall of 2008 all of the world's major financial institutions had been operating with formal models known as "value at risk," designed to put a number on the maximum possible loss resulting from each day's operations; when the abyss opened and their risk calculations were proved worthless, none of them knew where the contagion of incalculable loss and bankrupt firms might end, or which of them would survive it: The risks they thought they understood had reverted to unknowable harm (Leiss 2010).

The greatest and most fateful paradox, which is actually generated by in part by those already mentioned, is that the scientific basis of risk-taking and risk management may carry within it the seeds of its own spectacular, ultimate failure. For each successful targeted intervention in manipulating our relation to our environment on a minor scale makes us ever more dependent on being able to perpetuate the process of manipulation indefinitely into the future, on an ever larger scale. Each round of short-term, successful intervention induces the need for more extensive ones later on. Think of antibiotics and the development of microbial resistance to them. Or the case which I shall discuss more thoroughly in a moment, our inadvertent manipulation of the earth's climate system, from the burning of fossil fuels, which may require us to experiment with massive geo-engineering experiments in the future. We cannot jump off this treadmill.

Moreover, driven by the economies of scale and comparative advantage, the globalization of production of economic goods integrates the fates of nations and

regions every more tightly; now all want the additional industrial development pioneered by the West – and why shouldn't they? But this fact introduces the added complexity of requiring coordinated action through international agreements, something that in itself has been shown to have its own treacherous difficulties.

All of this leads to enormously increased pressures and impacts on the globe's key biophysical resources, including potable water, energy, agricultural soil, unpolluted air, ocean productivity, and others (again, I will come back to this issue in a moment). These impacts must be managed in order to ensure that the productivity of these resources can be sustained over long time-frames. One of the unintended consequences is the globalization of the associated risks, which results directly from our successes in risk management on a smaller scale. With respect to diverse threats from zoonotic diseases to climate change to systemic financial risk, we are forced to acknowledge that only a coordinated international effort will be adequate to the task. But it is not at all certain that our social institutions will ever be sufficiently robust to mount such an effort in any or all of these domains.

Managing Nature.

The general point I want to make is this: The long quest to exploit nature's resources intensively for human benefit threatens to reach its own internal limit and may collapse under its own weight. (I will explain what I mean by "internal limit" in a moment.) The reason is that this exploitation has unintended consequences that themselves must be managed, and that this management can only be done collectively, by all nations acting together; however, it is not at all certain that the will to do so can be mobilized. If it

cannot, the consequences of this failure may turn out to be catastrophic for humanity as a whole.

There is an interesting attempt being made by environmental scientists to define a set of so-called "planetary boundaries" for human transformation and exploitation of the earth's natural systems. In a nutshell, these boundaries determine the amount of the earth's biological productivity that can be sustainably harvested by human societies. Here the word "sustainably" has a precise meaning, namely, ensuring that natural systems are capable of regenerating themselves as we use them, so that future demands on them can be met indefinitely into the future. As presented in the journal *Nature* in 2009, by Johan Rockström and colleagues, these boundaries include freshwater use, ozone depletion, land use changes, the nitrogen-phosphorus cycle, ocean acidification, and climate change. The authors try to show that human demands on these systems either already exceed "safe" levels of exploitation, or are close to doing so; meanwhile, of course, human numbers and levels of exploitative demands are increasing steadily.

A more recent article, in the journal *Science* in 2012, by Steven Running, combines these determinants of planetary boundaries into a single indicator, namely, "terrestrial net primary plant production" (abbreviated as the "NPP boundary"). He notes that "plant matter [from solar energy, water, and atmospheric CO_2] … sustains the global food web and becomes the source of food, fiber, and fuel for humanity." He concludes: "Consideration of current land use patterns and the projected rise in the human population suggest that human consumption may reach the global NPP boundary within the next few decades." (This is in a way an updated version of the famous *Limits to Growth* argument from 1972; contrary to what many believe, as shown

in a recent review [Turner 2008], events in the intervening forty years have validated much of the business-as-usual scenario presented there.)

We have no "political" process in place, at the international level, that could even pretend to manage the future course of the human impacts on the earth's biological productivity. So let's just hope that these scientists are deluded.

Consider at greater length the issue of global climate change. This is part of the central story of the last few centuries, the story of the industrial revolution, because fossil-based energy sources are the principal driver and enabler of industrialism. Fossil energy use has been growing since the middle of the eighteenth century; by the mid-point of the present century, three hundred years later, in 2050, it will still represent about three-quarters of global energy demand. The story about the consequences of our energy use involves, first, the scientific theory of the natural Greenhouse Effect (2012), developed in the 19th century from Fourier (1824) to Arrhenius (1896), telling us why the earth is a full 33°C warmer than it would otherwise be in the absence of this effect.

The later theory of anthropogenic (human-caused) warming, known as the theory of radiative forcing, tells us that the massive amounts of greenhouse gases we have added to the atmosphere during the last three centuries, largely from the burning of fossil fuels, almost certainly will produce a range of adverse effects – changes to long-term weather patterns – of very large magnitude. This insight began with a famous paper by Roger Revelle and Hans Suess in 1957 (Revelle 2012). [I did my doctoral work at Revelle College at UCSD.] Beginning in 1965, a long series of expert panel reports published by the U. S. National Academy of Sciences, followed by a series of massive reports under the auspices of the Intergovernmental Panel on Climate Change (IPCC),

based on thousands of papers published in peer-reviewed scientific journals, confirmed this original insight. Almost certainly this is the largest collaborative undertaking in the history of modern science. Unfortunately, it showed that our manipulation of the earth's climate was inadvertent, and that we fully comprehended the nature of our actions very late in the game, making the deployment of any counter-measures both difficult and, ultimately, expensive.

This is actually a very hard problem, both of precise understanding and of action based on it. The earth's climate system moves massive amounts of energy around the globe and is the result of an extremely complex set of factors, including the nature of the sun's electromagnetic radiation, variations in the amount of solar energy, the tilt of the earth's axis, its rotation around its axis as well as its orbit around the sun, the capacity of its oceans to act as a carbon sink, the function of clouds, the heat-trapping potential of various gases, and others. This means that over long periods of time the earth's climate varies substantially. Thus the scientific account of climate is necessarily as complex as is its subject, and simulations – the so-called climate models – require the most powerful computers to run them. In fact, it is so complex that most of us have to take it on trust, as we do with all the rest of contemporary scientific output.

This is a very hard problem for other reasons as well, the most important of which is the time-frame for climate change impacts and the lag effect of radiative forcing. Lag effect means that we do not observe the ultimate results of human inputs to the climate system for a very long time, indeed, over many generations. And to put the point bluntly, we are bad enough at making sensible political decisions under conditions

where the evidence stares us in the fact, so to speak; when it comes to projections about what may happen far into the future, we are, frankly, quite hopeless.

The massive IPCC summary of the scientific analysis of climate change at present is encapsulated in the conclusion that anthropogenic greenhouse gases are "responsible for most of the observed temperature increase since the middle of the twentieth century." This conclusion is reported as "very likely" to be the case (>90% probability, with high confidence). Since we are still accelerating the process of radiative forcing, because our greenhouse-gas emissions are steadily rising, substantial future rises in temperature are inevitable. And indeed there is some plausible probability that in the relatively near future some massive positive-feedback loops may kick in, for example additional warming induced by the release of methane stocks now locked into Arctic permafrost, leading to the possibility of a "runaway" greenhouse effect.

At some point, likely before the year 2100, these temperature increases are likely to be very disruptive, in terms of our established life-styles, producing massive dislocations in human settlements. In a recent book (Leiss 2010) I have called this a "black-hole risk," meaning a risk with a potential downside so enormous in scope that we cannot even estimate how bad it might be.

Climate change is a global problem. It can only be dealt with in the context of an overall international agreement with specific and binding commitments, enforced by penalties, for the failure of any nation to meet GHG emissions reductions targets. This year, 2012, marks the end of a twenty-year period of failure, starting with the 1992 "Rio Conference" and continuing through the ratification and then abandonment of the "Kyoto Protocol," to achieve any such agreement. Will we succeed if we try again? Do

we even *want* to try? At present the answer is a resounding "No." [It's not that we haven't ever succeeded in doing this, as the international convention on ozone-hole depletion shows (see Leiss 2005). But in that case we had a nice picture of the hole in space, and the threat of elevated skin-cancer risk, to settle the public debate on the need for risk control.]

Climate risk mitigation requires controlling human-caused GHG emissions. Like all risk mitigation this will cost money, for example, by means of a carbon tax on every person's fossil-energy use, perhaps a small tax at first, but probably quite a hefty one later on. Who here today wants to start paying? Remember, you have to start paying *now* in order to avoid the really harmful consequences that "very likely" may befall your great-great-great grandchildren by the year 2100. Note that there is only a certain probability of these harms happening, albeit a high one (>90%). Admittedly, it's a lot cheaper just to hope that it won't happen after all, letting your distant descendants take their chances with the outcome of the bet you make today. Or to simply adopt the belief that the climate science predicting this outcome is a "hoax" – as many U. S. citizens do, according to opinion polls, apparently trusting the many web-based propaganda organs that promote this canard. [See the excellent PBS *Frontline* program, "Climate of Doubt," broadcast earlier this week.]

The United States is home to the largest, most lavishly-funded scientific enterprise the world has even seen. The mere suggestion that one of the crowning glories of that enterprise, climate science, could be a hoax – that is, a deliberate deception – is, or at least ought to be regarded as, simply ludicrous. But the fact is that the opposite idea, namely, that the science of climate change provides a plausible basis

for starting to pay a carbon tax now, cannot even be *discussed* in this country (the situation is not much better anymore in Canada, which once ratified the Kyoto Protocol). Just remember: Every belief we hold about the future is a bet. And in another 20 or 30 years it won't even matter which way we have bet on climate change risk: At current and projected levels of GHG emissions growth, by around 2050 we will have reached the point where any contrary action would be pointless (see McKibben 2012): Those alive at that point can all just join in singing *Que sera, sera*.

Everything we ordinarily believe in trusting the results of science in our lives, such as following medical routines and operating the countless gadgets we depend on, tells us that our bet against the believability of climate science is a very bad wager. Some people think that the only good bet is to trust our technologies to deal with global warming later on, if we are eventually forced to conclude that we need to counteract our radiative forcing, by geo-engineering: putting thousands of orbiting mirrors up in the stratosphere to reflect sunlight back into space, or producing more cloud cover by spraying huge quantities of sulfur dioxide into the lower atmosphere (thus mimicking the effects of volcanos), or dumping iron into the oceans to stimulate algae growth for carbon sequestration. If you think that, having failed to manage other types of human impacts on the planet, we are likely to pull off this one without a hitch, you are to be regarded as a true Panglossian.

At the gaming tables, when your bets have turned against you and you respond by raising the ante, it's called "doubling down." Here the size of the bet we are making, by pretending that everything is under control, with respect to our manipulation of the planetary ecosystems, is approaching the "all in" scenario. It is in my view not an

exaggeration to say that we are wagering on the future of industrial civilization itself. For myself, I doubt whether this will end well. [Some of you in this room will be alive in 2050, when the future course of this risk scenario will be a lot clearer than it is now. Please remember to send the rest of us who are no longer with you an email message; for myself, I hope to be partying with the Devil, so you can reach me in Hell.]

Humans are a clever and adaptive species and would surely survive such a catastrophe. But the current revival of interest in the thinker who is perhaps the greatest political theorist of the modern age, Thomas Hobbes, should remind us that life once was "solitary, poor, nasty, brutish and short," and might be so again.

Conclusion: The Inner Contradiction within Risk Management.

The deep truth about risk and risk management has to do with our propensity to push our wholly inadequate managerial capacities to the limit, all the while protesting that no such limit exists. Our reaction to encountering unforeseen obstacles is to "double down" on the first bet, raising the stakes dramatically: If climate change risk arises from the technologies that allow us to combust fossil fuels on a prodigious scale, we are inclined not to hedge the first bet but rather to double it by envisioning using entirely new technologies on an equivalent scale to counteract the initial effect. To take another specific example, there is the notorious case of Bruno Iksil of JPMorgan Chase, known as the "London Whale" for the sheer size of his bets, who apparently, earlier this year, "doubled down" repeatedly as the markets turned against his bet, until his bank was forced to exit his positions in the derivatives markets at a cost of $7 billion and counting. This case shows that bankers reacted to the damage done by exotic financial instruments in the 2008 financial crisis by deploying risk control strategies so complex

that, it seems, not even the bank's senior management personnel and its CEO understood what their traders were doing or how much the potential hit on the downside could add up to.

I remain, I confess, an incorrigible Hegelian. In this failure to understand how the most exquisitely-tuned rationalism can magnify, rather than mitigate, our vulnerability to the downside risk, can delude us into imagining that we have become the unchallengeable masters of our planet's ecosystems, and can tempt us into wagering all of the accumulated gains of the last few centuries on a few final throws of the dice, I see the cunning of unreason at work.

Do you recall Goethe's marvelous poem from 1797, "The Sorcerer's Apprentice" (2012), where the hapless assistant overestimates his ability to deploy safely his master's magic incantations? The risk managers I just mentioned probably think that this is an entertainment for children because Walt Disney made an animated cartoon out of it. How little they know.

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