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Scientific Restraint: The Balance between Progress and Safety

Richard Bell
University of Rhode Island, richard_bell@mail.uri.edu

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Richard Bell (richard_bell@mail.uri.edu), Computer Science & Writing

Sponsor: Dr. Timothy Henry, Computer Science

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It is said that, “A house divided against itself cannot stand” and such a truth can be accurately applied to today’s scientific community. The progress of science and technology has brought mankind countless innovations, particularly over the past century, and its continued role as an important motivating force in our lives is virtually assured for the foreseeable future. As it stands, however, science is deeply divided: politically, ethically, financially. Instead of a concerted cooperation among the entire community to move forward, factions have arisen, and with them unhealthy competition and misinformation that, at best, suppresses our collective growth and at worst could lead to widespread disaster.

With the great variety of conflicting goals and motivations present in the current political and scientific realms, one would be hard-pressed to declare any universal rule-of-thumb for responsibly conducting activity in experimental fields. Some would promote the unfettered expansion of scientific activity, reasoning that increased knowledge of our world can only improve our lives, while others strongly support restrictive scientific reach, proceeding only when any possibility for damaging results has been minimized or completely eliminated. Few would agree that either school of thought is appropriate all of the time, with unrestricted expansion paving the way for abuse, irresponsible dissemination of resources, and disaster of all kinds, while an abundance of restrictive measures guarantee safety and control, but slows the learning process to a crawl and inhibits the creativity of potential experimenters; after all, an experiment isn’t really an experiment if the outcome is already known.

It seems logical that the best possible compromise lies within the vast expanse bridging these two opposing ideas, but a great deal of boundaries exist in pinpointing this ideal procedure. Ideally, governmental bodies could forge a rational compromise, and the corporations and citizens would follow it, using their own vehicles of change to influence those laws that seem inadequate, as seen in Figure 1. Realistically, however, the financial and social institutions often have just as much sway, and sometimes more, than government bodies, creating the equally divided playing field depicted in Figure 2. Some governments, corporations, and individuals are leaning towards greater scientific freedom, while others emphasize cautious progress. Indeed, the very orbs of influence expounded by these power structures (the individuals under the control of the government, the individuals that control the government, and the corporate entities that operate within and beyond these globes of control) are the source of much of these disagreements, as each have their own balance of power to maintain, which are subject to the political, economic, and moral interests espoused by controlling entities within them. And beyond all of these broad characterizations, there exists the fact that individual people are not

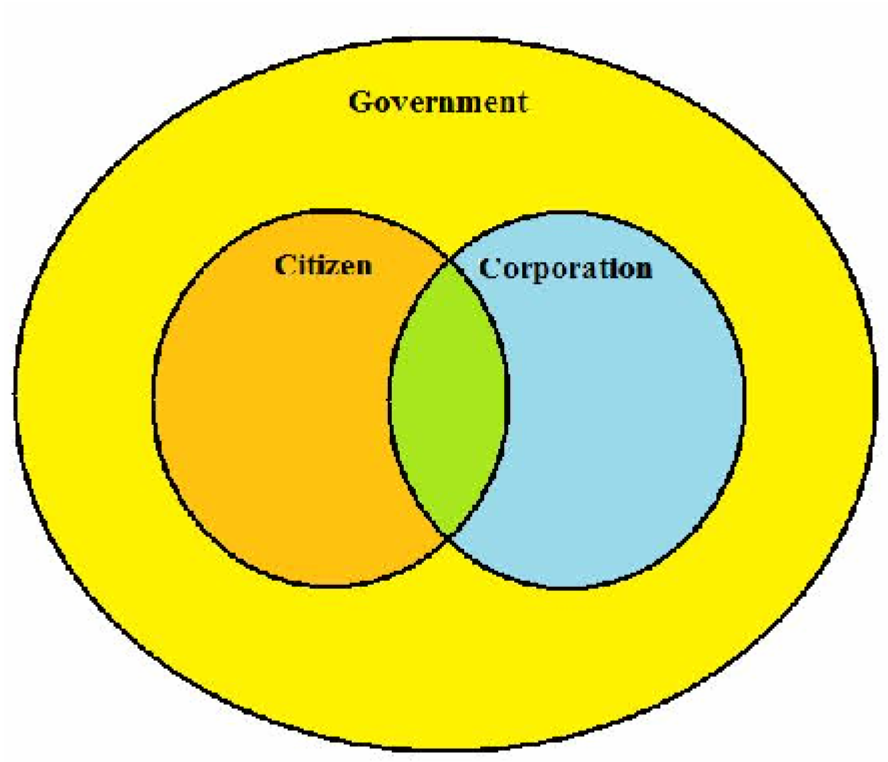

Figure 1: General power structure under ideal circumstances, where the government has the last word of matters of restraint.

as black and white as the caricatures created by their leaders and the media would have others believe, and that even in controlling environments (and perhaps because of them) dissention is bound to occur on some level, creating unforeseen divergences within the system.

<u>Defining the Problem</u>

Before trying to breakdown this seemingly infinite multitude of competing decision-making factors, putting a definition to the restraint necessary at some level, to some extent, is of the utmost importance. In broad terms, scientific restraint revolves around the concept of rethinking or downsizing experimental projects in consideration of safety concerns, built upon risk management and/or ethical and moral ideals. Adding the coda of ethical and moral influence may seem unnecessarily vulnerable wording, as it leaves open the possibility for stilted or heavily biased groups to interpret them to their own ends; for instance, a racially or religiously prejudiced regime could see the creation of an ethnically-targeted genetic disease as morally acceptable by their own extremist belief system, but which would be strongly malignant to others. However, barring some sort of machine-based decision-making body,

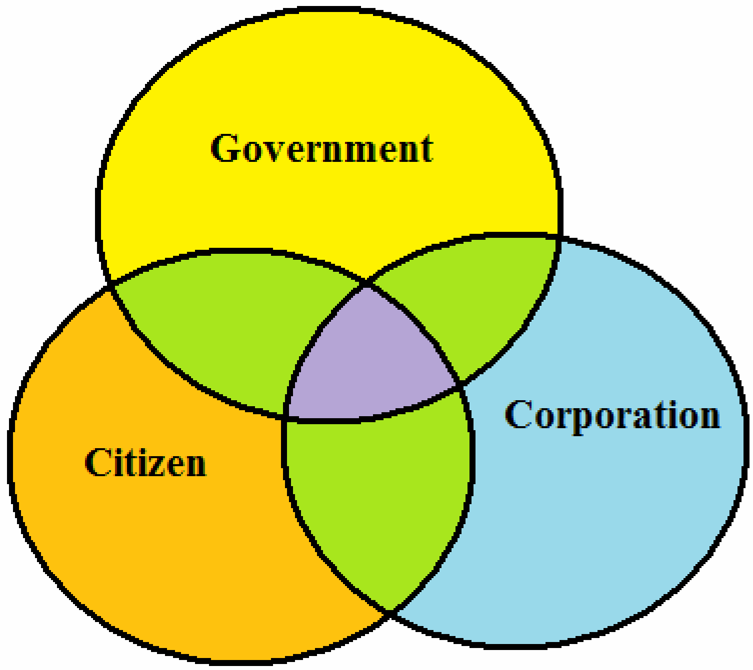

Figure 2: More realistic breakdown of power, with citizens exercising power through mediums outside the control of most governments (e.g. the Internet), corporations through geographic expansion into lesser or uncontrolled areas, and both through illicit means.

emotionally founded opinions and leanings will inevitably find their way, at least incidentally or indirectly, into some facet of decision-making processes. The current human element is reliable to predict only in that an x-factor should always be expected, even if its nature is inconsistent and unknowable. This x-factor can take the form of any number of beliefs, ideals, prejudices, obsessions, or strategies: personal leanings and motives that can be generated by a wide variety of personal, experiential, or intellectual events. For example, a person with a paralyzed family member may push stem-cell research, as such progress would mean a great deal to him and his family.

Beyond the weights of personal value systems, however, restraint, particularly through risk management, is a necessary existent even in basic decision-making, as the possibility for success must be compared against the possibility for disaster. Managing risk responsibly is imperative on virtually all levels of project development, ranging from calculating the probability of financial loss in pursuits that may not prove profitable, to creating relationships with parties that are not corrupt, inexperienced, or overly biased, to evaluating the possible damages incurred if a product malfunctions in a worst-case scenario. In many situations, choices may have to be made in weighing projects with a high probability of errors with minor repercussions to one with a low probability of error with major repercussions. For example, standard automobile tires fall within the former category, as blowouts and flats are common, but harm to those is typically minor and very localized. The Large Hadron Collider, however, represents the ladder category, in that the risk of such a device creating an Earth-swallowing black hole is theoretically possible, but highly improbable. Since both of these products are currently in use, the void between these extremes holds a vast number of projects whose probabilities for disaster and loss widely vary and upon which adjudications must be made as to the necessity of progress in their fields. Again these scales of pay-off versus cost are open to individual interpretation, although by default they are anchored by the numerical economic system, which is often used to judge the viability of a project or expansive direction when human and environmental costs are less clear; in other words, a deciding factor without moral initiatives, whose goals are solidly financial in nature.

The Perils of Scientific Expansion in a Politically Divided World

The difficulties associated with agreeing upon where to designate the boundaries of responsible restraint in the vast pool of scientific relationships and scenarios are further exacerbated by powerful, separate governments with conflicting values. In pursuing contrary lines of exploration or, more commonly, pursuing high-risk projects competitively, the stage is set for unhealthy scientific proliferation. Exploration for spite or intimidation limits the profitability of such projects even when they are developed tirelessly, as energy is both invested in unproductive posturing and divided by nation instead of joined cooperatively.

Yet who makes and enforces these limitations? Again, due to the trisected power structure mentioned earlier, this is not an easy answer. Governments can attempt to enforce scientific restraint through laws and legislature, industries through regulations and financial support, and special interest groups and the media through public opinion and perception. Of course, within the realms of legality, the word of the government is largely held above those of the companies and the civilians, though it can be, and often is, swayed by enough influence, and money, from these two sectors. Even if the word of the government denies the opinions of these two large, but fairly segmented, power structures, it must keep in mind the unspoken threat of these influential tiers uniting within or amongst themselves to show their own disapproval, seen in the occurrence of revolutionary or reformatory movements and redirection of corporate funds and support.

It is the ebb and flow of power amongst the various factions that inhabit these tiers that makes definitive scientific restraint so difficult to both agree upon and effectively impose. Such an historical example of this can be found in the development of nuclear weapons over the past half-century or so. The Cold War's nuclear stockpiling created a natural balance of power, as the sheer potential of this technology kept both sides intimidated enough not to force the hand of the other. In such a high-risk case, only the governmental tier of control has any real say in the balance; though the citizens may voice their opinions and corporations may support or benefit from the government advances, their backing is not required as the maintenance of such technology is seen as pivotal to the all-important "national security".

Alas, the tension that was eased by this technology's development only fed paranoia on both ends, provoking further production, and embodying the cyclical process that kept the Cold War atmosphere alive for so long. Normally such escalating anxiety would build to a destructive head, in this case global thermonuclear war, but the mind-bending results of such an outcome were ultimately avoided largely due to their unspeakable cost. Instead, these tensions found exhaust vents of their own through conventional means while eluding all-out combat between the two superpowers, either through wars by proxy, such as those in Korea and Vietnam, or through diplomatic and economic sanctions. The Cold War ultimately ended in a whimper rather than a bang, as the Soviet Union found itself economically unable to keep up with America's military expansion, but the world had tired of nations flirting with disaster through global fallout.

The out-of-control proliferation of nuclear weapons by the United States and the Soviet Union taught world powers the value of imposing shared regulations on such high-risk technology. Decades of an expansive arms race, and the posturing and conflict arising from the unrestrained production of this technology, threw the planet into an often-tense Cold War. As the number of warheads continued to sky-rocket, the risk of nuclear annihilation grew, but not because the military threat became greater: both Cold War superpowers soon possessed arsenals capable of a global extinction event several times over, which rendered continued production moot; however, as the number of nuclear weapons grew, so did the number that needed to be serviced, disseminated, updated, and tested, all of which had the potential to create an accidental detonation that could trigger an apocalyptic exchange. Ultimately, these newly built weapons were contributing nothing to defense, acting merely as tools for posturing and opportunities for both man- and machine-made disaster.[1]

By the time the Test Ban Treaty (TBT) came about, the United Kingdom, France, and China had officially joined the nuclear club, but all agreed that such aggressive warhead stockpiling should be avoided at all costs. The TBT, and its later incarnations, however, were not enough to solidify the existing nuclear powers' monopoly on such weaponry. As India, Pakistan, Israel, and North Korea gained nuclear capabilities, the true inability of the United Nations, and any other international organization for that matter, to impose rule on independent nations was fully realized.[2]

Such is the weakness of a world partitioned by hundreds of individual governmental systems: when no one can agree, less cautious or bolder nations may pursue delicate lines of experimentation, risking not just themselves but those who responsibly chose to avoid such procedures. The same quandaries apply to regional reservations involving gene therapy and stem cell research, where regimental stigmas, which may or may not be backed by cultural mores and business interests, are only applicable in specific geographic areas. Just as nuclear proliferation threatened human civilization, these experimental procedures carry their own risks, as germ-line transference in gene therapy has the potential to disperse as an epidemic and stem-cells bring up questions regarding quality of life.

Viewing Potential Disasters: Myth vs. Inevitability

Yet how likely is it that a scientific experiment could lead to disaster on a large-scale? Man's relationship with technology has created incidents of lesser magnitude before, such as the meltdown at Chernobyl, but the infrequency of direct scientific causality in a high death-toll incident leaves many skeptical of its probability. Like the driver who has never wrecked, we gradually attain an unfounded sense of infallibility, and push the limits farther. Some could argue that one example of this is unfolding right now, as global climate change continues to take the backseat to economic expansion, but again, although accidents happen, science is not found directly to blame and is allowed to continue unhindered.

Such is the fact that anyone who mentions wide-scale destruction, perhaps even on an extinction level, largely gets dismissed as a fear monger, a radical, or a loony. Compounding this is a recent flare in the mass media's embrace of supposed doomsday plots, with cable channels like the History Channel embracing sensationalist programming based on such theories, and an increasing number of post-apocalyptic science-fiction films being released. The often mediocre reception of high-profile productions dealing with this subject matter[34567], and the fact that none of them have ever come to fruition, has caused the vast majority of any findings pointing to a potential, worldwide disaster to be discredited in the eyes of the public, ranked alongside doomsday theories of the 2012 Mayan calendar, which has, at times, replaced "What killed the dinosaurs?" as the favored, slow-news-day filler. Essentially, the media's saturation of its audience with doom-and-gloom content is gradually reducing the power of potential doomsday scenarios to arouse fear in the general public, with increased exposure leading to higher tolerance and association of that topic with fiction. As a result, anyone writing to an audience outside of a specialty publication is forced to downplay any chance of world-ending repercussions in order to avoid being disregarded altogether.

So how likely is an extinction-level event to occur? As one would expect, measuring such a process is not easy and is far from reliable. Professor J. Richard Gott's predictive technique is one of the most well-known, but is based purely on unproven assumptions[8]. His theory is founded on the assumption that, for any given individual in a class of entities (i.e. one person in the human race) there is a ninety-five percent chance that the selected individual is in the middle ninety-five percent of that entity's lifespan, from conception to extinction. From this broad, but fairly acceptable assumption, Gott is able to calculate the likely longevity of this entity. As expected, however, this produces some widely varying results. For example, when the human race is applied to Gott's reasoning, we are given somewhere between 5100 and 7.8 million years left before extinction. Such results are so vague so as to be written off as pure arbitration. Likewise, when applied to people and institutions that have already reached their conclusion, Gott's method is often accurate, but seemingly only by chance. Unfortunately, trying to narrow results does little for the results' respectability, as the smaller the percentage considered the center of existence, the less likely it is that the actual entity resides there.[9]

A competing predictive method was devised by philosopher, John Leslie, and is again based upon sampling. According to Leslie, since sampling size tends to grow with time (i.e. human population size) a visualization of such would look like a triangular wedge, with the very lowest point at the species' origin and a tall column representing its end. By his reasoning, since there is a far greater number located just before an extinction event, any given person is far more likely to fall just before the end than farther towards the beginning or in the center. What may initially seem like a sound notion falls apart when one tries to apply it to everyday entities. By Leslie's reasoning, any given person one meets or place one visits is near the conclusion of its existence simply because its existence is interpreted as a derivation of random sampling according to Leslie's view. Since it seems rational that the mere existence of an entity should not preclude its immediate downfall, this demonstrates that this sampling is not nearly as random as it is assumed to be (which it isn't since our sample was an explicitly selected moment in time). But even if his sampling is faulty, could Leslie be right? It's possible: if a huge asteroid struck the Earth or nuclear war began tomorrow, his reasoning would be correct and the species would meet its downfall at the height of its population. However, like Gott, Leslie's methods, though logically sound, do not translate to the real world and its infinite x-factors, and ultimately such methods of prediction are vague at best and pure guess-work at worst.[9]

A third school of thought is less quantitative and, ironically, likely to appeal to both the realist and the optimist. Scholar Marshall McLuhan believed that divergences in opinions and knowledge, such as those pertaining to the limits of science and the weighing of potential payoff against potential disaster, will never breakdown to the point of total annihilation thanks to the gradual growth of a "global village". This term, coined when the earliest seeds of the Internet were just being planted, describes an electronic community spanning all of human civilization, boiling down all diverging thoughts into a usable form:

> "Our electro-magnetic technology is transforming the sensory patterns of humanity so rapidly and radically that all problems relating to knowledge and the morality of knowledge simply cease to have pertinence or credibility. Logical difficulties, they insist, are the consequence of a 'linear thinking' imposed by the technology of print, which is now happily falling into desuetude. The brave new electric world our children are now enter-ing will bring mankind into the multi-dimensional, audile-tactile, anodyne togetherness of the 'global village', where schools and all other formal institutions are, or shortly will be, irrelevant".[10]

Essentially, the restructuring of our thought process and the connection of countless minds through communications technology will create new forums for solving problems and making decisions, thus technological progression saving us from itself. McLuhan's ideas are abstract and certainly idealist in nature, though the exponential growth of Internet and communication technologies, both through emerging markets in the developing world and in new formats in developed countries, certainly does seem to be paving the way toward advanced connectivity, leaping political, ethnic, and religious boundaries. Such notions of a world united under one community harkens back to the Type I civilization described by the Kardashev scale, where the entire species is able to overcome localized and national stigmas in order to achieve optimum scientific progress, and ultimately quality of life, for its people[11], although we have as yet only achieved a level of about .72 in respect to energy growth[12]. Though it lacks the mathematical backup that Gott and Leslie produced for their theories, McLuhan's seems more in keeping with the nature of human society, with the online community playing a greater role and becoming entrenched even deeper in day-to-day life, and although it may never be realized to its full potential, it certainly seems a worthwhile goal to pursue, if no other reason than it does not end in our total destruction.

So if it is impossible to predict, with any reliability, the likelihood of failures and disasters based on the timescale of a project's existence, logically the responsibility of avoiding costly defects lies in careful planning and informed decision-making. All of this is easier said than done, however, as a multitude of diverting factors complicate reliable regulation and enforcement. A politically-divided planet such as ours' adds regimental prejudices to existing religious and moral ones, creating perceived competition on many levels. In addition, the scope of laws, both domestic and international has its limits, and if a party wishes to pursue illicit scientific activities it will undoubtedly find a way to do so, either by moving to countries with less stringent policies or by covertly conducting said activities under the radar of their nation of residence. Consequently, those who operate outside of the law typically do so for a reason, as those with responsibly, rationally derived projects and who displayed necessary expertise, restraint, and foresight would be able to garner support through legitimate channels. Indeed, the attraction to explore fields forbidden by the law (such as human cloning) is often enough to propel some individuals to entertain such prospects. In addition, the renegade nature of underhanded exploits means that such practitioners are not privy to the security measures and resources of legal means, giving error due to ignorance or mishandling an increased likelihood. In other words, responsible individuals are entrusted with the resources to engage in experimental activities, while those lacking such skills who choose to pursue risky goals anyway often do so in less-than-ideal environments.

Even the most mundane mistakes by man or machine can spell disaster reaching far beyond the scope of those immediately involved in its undertaking, a fact that has frequently been seized upon by the media; one well-known example, however fictional, of such an error can be found in Stephen King's *The Stand*, where a mere malfunctioning gate leads to a plague's escape from a military base and devastation around the globe. The scenario of one technology bringing disaster by unforeseen circumstances was discussed even earlier in Michael Crichton's *The Andromeda Strain*, where a satellite brings back a lethal disease from outer space. Thus far, no experiments have created an incident this catastrophic in magnitude, but these works do exemplify how the best laid plans can be thwarted by subtle, unpredicted disturbances; this point, alone, should give those who would push the limits of responsible science second thoughts, as the safety of an experiment or laboratory is often completely taken out of the experimenters' hands, subject to both nature and chance. Still, the fact that no incidents have triggered a wide-scale disaster causes many to brush aside such possibilities, regardless of the fact that they are at least theoretically possible and that the cost is truly incalculable.

Knowledge of this fallibility is what has kept the human race from straying too close to the precipice of disaster in exploring our scientific reach and technological expansion. We learned the potential cost of error, thankfully, through stumbles rather than falls (e.g. the U.S. military's "Broken Arrows"[13] and a number of false detections of nuclear launches[14]), and in acknowledging the potential for mistakes in high-risk scenarios, we've been better prepared to handle such situations as they arise. However, as science moves into increasingly experimental fields, such as nanotechnologies and biotechnologies, the stakes are growing increasingly higher in these largely unexplored areas where in some cases results can be unforeseen. Some people point to CERN's Large Hadron Collider as a probable opportunity for science to go on a rampage, due to a possibility (albeit extremely miniscule) that a world-ending black hole could develop; such thinking does serve a purpose in that it forces people to weigh the necessity of an experiment against the possibility of an incredibly improbable extinction event.

Man wandered into the realm of triggering his own demise with the detonation of the first nuclear bomb, where scientists risked setting the atmosphere afire to supplement defensive capabilities, and even centuries before the nuclear age, when biological warfare in the form of plague victims' bodies being hurled into enemy castles and measles-infected blankets given to Native Americans demonstrated man's ability to spread destruction on a wide scale. Since then, our technologies have brought many new opportunities and risks to the forefront. Ultimately knowledge of our own capabilities and limitations is the best deterrent to human error and the best advocate for scientific restraint. The increasing focus on scientific subjects in education systems around the world brings with it the hope that widespread knowledge and international cooperation can create a scientific environment that is simultaneously accessible and self-regulated, aware of its responsibility to learn without putting others in danger. Some might point to rogue states and imbalanced or immoral individuals who would pervert science for their own selfish or malicious needs, counteracting the reasoning of their entire field. In an attempt to weed out such fringe elements, one might advocate something like a global police state, simultaneously unifying scientific regulations and monitoring the activities of those who might defy what is best for the greater good.

However, such attempts would likely create as many problems as they resolve, with such a system stifling creative experimentation and diverse project funding, while leaving the very possibility that such a bureaucracy, stretched as it would be across every land and people, would be unable to effectively watch for every potential breach. Those who would run such a system are human too, after all, and subject to the same ineptness, ignorance, prejudice, and corruption of which today's politicians are capable. And even in an ideal governmental system, there are enough people and enough places to hide, so that anyone with a whim to defy the social order will find a way to do so.

<u>The Solution</u>

The most promising way to approach responsible levels of scientific restraint on a global level should begin with the sharing of technical information across state boundaries. This does not mean that governments should give away military secrets, but it is important for vital scientific knowledge to be disseminated widely. In this way, the greatest number of minds and resources can be given to refining and harnessing these ideas, thereby speeding up progress in these fields and possibly improving quality of life for a far greater number of people than if the information had been reserved for only domestic application. Another, perhaps just as important, reason to share knowledge is the trust it builds between nations. One of the greatest limits to pursuing restraint is the lack of trust among different peoples, often even between allies, and an open exchange of information would at least encourage political leaders to consider pleas of restraint if a scientific relationship has developed. Not only would this result in safer progress, but it would allow science to become less of a competition and more of a group effort. So while this availability does allow hostile fringe elements access to information, it more importantly facilitates knowledge transfers among legitimate sources, which can in turn work together to combat malignant elements.

In building this international trust, the movement would be greatly assisted by some kind of open, international forum. Such a body would consist of governmental leaders, from as many nations as possible, openly conversing with panels of scientists and risk management experts so as to make informed, responsible decisions as to what experimental projects are safe, or even just deserving of investments of time and resources, in pursuing. Such a forum would preferably be formed under the United Nations, since virtually all nations are already members. They would be a preferable sponsor, as their unbiased structure would circumvent the sway of larger nations without alienating them. Although there would still be disagreements, both among politicians and scientists, this atmosphere would be a positive one for airing such grievances and uncertainties as the goal is ultimately planning mankind's most potentially-rewarding, scientific future, if nothing else affording the greater international community the ability to rationally discuss issues pertaining to secure, rational scientific progress in an informed environment.

Without such an international scientific relationship, or perhaps in spite of it, what this issue boils down to is that the free will and individuality of mankind means that changing our world or our governments really will not decisively rule out the chances of scientific misstep nor will it instill in all a sense of restraint and accountability when gravitating towards the unexplored depths of science and technology. Although some would be wont to throw up their hands in a dismissive acceptance that whatever will be, will be, doing so would be truly irresponsible. While curiosity is a natural human emotion, knowledge is an invaluable decision-making asset and as such should be utilized in educating the scientists and would-be scientists of this world in the necessity of restraint in such potentially volatile environments. While this could be done in any number of ways, from courses focusing on it in schools, special watchdog committees created by national and international groups, or increased awareness via the media, mankind's increasing role in our destiny as a civilization must be ingrained in us as a people, so that abuses of scientific knowledge can be handled and irreversible errors avoided. Only then can we say with any certainty that our intelligent expansion has been a reasoned one, and even then we must be ready to accept responsibility for when our greatest preparedness fails, as in the words of Robert Burns, "the best laid schemes of mice and men go often askew".

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