NOTES

"HONEY I BLEW UP THE WORLD!": ONE SMALL STEP TOWARDS FILLING THE REGULATORY "BLACK HOLE" AT THE INTERSECTION OF HIGH-ENERGY PARTICLE COLLIDERS AND INTERNATIONAL LAW

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I. INTRODUCTION

On September 10, 2008, scientists at the European Organization for Nuclear Research (CERN) turned on the "largest, most powerful particle collider," and the most expensive scientific experiment, in history.[1] Physicists throughout the world hope that the Large Hadron Collider (LHC) will allow them to observe previously unseen subatomic phenomena, and will give them insight into how the universe looked "trillionth[s] of a second after the Big Bang."[2] However, the excitement surrounding the launch of the LHC has been tempered somewhat by speculation that the experiment may prove to be a "doomsday machine"[3] that will bring about the end of the earth—and maybe the universe.[4] The alleged disasters include a range of terrifying scenarios such as the LHC's production of earth-swallowing micro black holes and the conversion of all the earth's matter into a super-dense glob called a "strangelet."[5] Because of these perceived risks, some scientists have gone so far as to file lawsuits in the United States District Court for the District of Hawaii[6] and the European Court for Human Rights[7] to enjoin the use of the LHC until after further study of its possible effects.[8] While many scientists are down-playing the threat of these potential catastrophes, even those who claim the LHC is safe acknowledge that there is a "dice-throwing nature" to quantum physics and that there is "some probability of almost anything happening."[9]

The controversy surrounding the LHC is the most recent iteration of an on-going debate among scholars and scientists about "how to estimate the risk of

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[1] Dennis Overbye, *Protons and Champagne Mix as New Particle Collider Is Revved Up*, N.Y. TIMES, Sept. 11, 2008, at A12.

[2] *Id.*

[3] *See id.* (citing worries of some who believe that the LHC could produce a black hole).

[4] Dennis Overbye, *Asking a Judge to Save the World, and Maybe a Whole Lot More*, N.Y. TIMES, Mar. 29, 2008, at A1.

[5] *Id.*

[6] Sancho v. U.S. Dep't of Energy, 578 F. Supp. 2d 1258 (D. Haw. 2008).

[7] Complaint, Rössler v. Switzerland (Eur. Ct. H.R. 2008) [hereinafter *Rössler* Complaint], *available at* http://lhc-concern.info/wp-content/uploads/2008/09/mr-beschwerde-cern-volltext.PDF. The application for injunctive relief was dismissed shortly after it was received by the European Court of Human Rights in August 2008. Joanna Sugden, *Large Hadron Collider Will Not Turn World to Goo, Promise Scientists*, TIMES, Sept. 6, 2008, *available at* http://www.timesonline.co.uk/tol/news/uk/article4682260.ece.

[8] *See* Overbye, *supra* note 4 (noting that the U.S. suit sought "a temporary restraining order prohibiting CERN from proceeding with the accelerator until it has produced a safety report and an environmental assessment").

[9] *See id.* (referencing a particle theorist's remarks who later stated there is also a probability that " 'the Large Hadron Collider might make have dragons that might eat us up' ").

groundbreaking experiments and who gets to decide whether to go ahead."[10] Part of the problem is that "society has never agreed on a standard of what is safe . . . when the odds of disaster might be tiny but the stakes are cosmically high."[11] Indeed, as stated by one scientist, one of the most basic questions, "How improbable does a catastrophe have to be to justify proceeding with an experiment?' seems never to have been seriously examined."[12]

This Note will consider the current debate surrounding scientific experiments like the LHC by briefly examining the history of particle accelerators and the LHC controversy, discussing the purported risks posed by the LHC and discussing possible responses by the international community designed to address safety concerns and regulate these experiments.

Part II looks at the history of particle accelerators, focusing primarily on those at CERN. Part III discusses the current controversy surrounding the LHC, including what scientists hope to gain through this experiment. Part IV shows the various disaster-scenario theories and reactions of the scientific community and others to these alleged dangers. Part V presents two specific legal challenges to the operation of the LHC and discusses why those challenges have been unsuccessful thus far. Part VI addresses why this area of science is ripe for an international safety agreement and recommends the specific components that should be included in such an agreement.

II. A "CRASH COURSE" ON CERN AND PARTICLE-COLLISION RESEARCH

CERN's campus "straddle[s] the French-Swiss border west of Geneva," Switzerland, and is a scattered collection of buildings occupied by thousands of scientists from universities throughout the world.[13] Several forward-thinking scientists founded CERN as a means to staunch the flow of scientists from post-war Europe to the U.S. and to create a center for European scientific excellence.[14] In 1952, eleven countries met in Amsterdam and agreed to create an intergovernmental organization to achieve these goals—the *Conseil Europeen pour la Recherche Nucleaire*—now known commonly by the acronym CERN.[15] CERN formally began operations in Geneva in 1954 with

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[10] Dennis Overbye, *The End Is Nigh! A Big Stakes Suit to Save Us All*, INT'L HERALD TRIB., Mar. 31, 2008, at 2.

[11] Dennis Overbye, *Gauging a Collider's Odds of Creating a Black Hole*, N.Y. TIMES, Apr. 15, 2008, at F2.

[12] *Id.*

[13] Renske Heddema, *Universal Appeal*, SWISS NEWS, Aug. 1, 2002, at 20.

[14] *Id.*

[15] *Id.*

twelve signatories to its founding Convention,[16] and since then has grown to include twenty member states.[17]

CERN has a long history in the field of particle accelerators, dating back to its first accelerator, the Synchro Cyclotron, built in 1954.[18] In 1959, CERN commissioned a second particle accelerator, the Proton Synchotron, which is still used today to provide subatomic particles to the other accelerators at CERN.[19] In 1971, CERN commissioned the Intersection Storage Ring (ISR), which ran until 1984 and was the first accelerator at CERN to collide two beams of protons.[20] CERN commissioned the Super Proton Synchotron (SPS) in 1981, and experiments with this accelerator led to the discovery of the W and Z bosons for which CERN scientists Carlo Rubbia and Simon van der Meer won the Nobel Prize in 1984.[21]

To further study the W and Z bosons, CERN built the Large Electron-Positron collider (LEP), which began operation in 1989.[22] The LEP conducted experiments colliding electrons and positrons at energies of up to 100 gigaelectronvolts (GeV).[23] As scientists pushed the LEP to higher energies, they began to catch glimpses of what they believed to be one of the most sought-after particles in physics: the Higgs boson.[24] Scientists at CERN asked

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[16] *Id.*; Convention for the Establishment of a European Organization for Nuclear Research, July 1, 1953, 200 U.N.T.S. 150 [hereinafter CERN Convention].

[17] Heddema, *supra* note 13, at 20.

[18] Paul Varley, *Underground Structures at CERN*, 9 WORLD TUNNELLING 367, 367 (1996).

[19] *Id.*

[20] *Id.*

[21] *Id.*; *see also* Dennis Overbye, *Replaying the Universe's Birth: Physicists at CERN Plan the Subatomic Bash of a Lifetime*, INT'L HERALD TRIB., May 15, 2007, at 2. Overbye explains that W and Z bosons are responsible for the weak nuclear force that causes some radioactive decays. *Id.* Bosons are packages of energy that "transmit forces . . . back and forth . . . between matter particles[, and are] closely related to photons, which transmit electromagnetic forces" also known as light. *Id.*

[22] Overbye, *supra* note 21.

[23] Stephen Battersby, *Bulls Eye*, NEW SCIENTIST, Aug. 26, 2006, at 36. This article also explains that an "electronvolt (eV) is the kinetic energy that a single electron would gain by pinging from the negative to the positive terminal of a 1-volt battery. A proton has a rest mass of 938 million electronvolts; the lightweight electron merely 511,000 eV." *Id.* The eV is the unit that particle physicists use to measure mass. *Id.* One billion eV is equivalent to 1 GeV. Dictionary.com, Gigaelectron Volt, http://dictionary.reference.com/browse/gigaelectron+volt (last visited Nov. 6, 2009).

[24] Frank Close, *Giving up the Ghost Trail: Has the Elusive Higgs Boson – Known as God's Particle – Been Found or Not?*, GUARDIAN (U.K.), Sept. 21, 2000, at 2; *see also* Elizabeth Kolbert, *Crash Course: Can a Seventeen-Mile-Long Collider Unlock the Universe?*, NEW YORKER, May 14, 2007, at 68. Kolbert explains that the Higgs particle creates an invisible field that acts like "cosmic molasses." *Id.* As particles move through it, the Higgs field gives mass

for more time to investigate whether they had found the phantom Higgs particle, but the LEP was scheduled to be shut down to make way for the LHC.[25] The LEP was decommissioned in November of 2000[26] with scientists at CERN fearing the honor of finding the Higgs boson would go to the Tevatron collider at Fermilab, the American national physics laboratory.[27]

III. THE CURRENT CONTROVERSY AND THE LARGE HADRON COLLIDER

The LHC, conceived in 1994, lies in a seventeen-mile circle 328 feet below the surface of CERN's campus,[28] and is built in the tunnel that previously housed the LEP.[29] Using super-conducting magnets, the LHC is designed to accelerate two streams of protons in opposite directions to more than 99.9% of the speed of light (over 186,000 miles per second), and will then shift the two streams onto a head-on collision course.[30] These proton collisions will occur at seven teraelectronvolts (TeV), seven times more powerful than collisions in the Tevatron collider at Fermilab, the next largest collider in the world.[31]

The LHC began operation at 4:28 AM Eastern Standard Time on September 10, 2008, circulating a "beam of protons" around the collider's seventeen-mile track.[32] Just a week after its initial run, however, the collider suffered a setback when a faulty electrical connection caused two superconducting electromagnets, used to steer protons in the LHC, to heat up, melt, and cause helium to leak into the collider tunnel.[33] Because of the time required to repair the magnets and the fact that CERN does not run colliders in the winter due to the increased cost of electricity, the first collisions will not

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to particles that would not otherwise have any. *Id.* Without the Higgs field, "physicists [would] have no way to explain why fundamental particles weigh anything at all, since, according to theory, they should be massless." *Id.*

[25] *See* Dana Mackenzie, *Vital Statistics*, NEW SCIENTIST, June 26, 2004, at 36 (stating that CERN scientists were only "granted one more month" for investigation).

[26] *Id.*

[27] *See* Jonathan Leake, *Big Bang at the Atomic Lab After Scientists Get Their Maths Wrong*, SUNDAY TIMES (U.K.), Apr. 8, 2007, at 3 (as one LHC researcher observed: " 'Ironically, this delay could be all they need' ").

[28] Colin Nickerson, *Scientists Hope Collider Makes a Big Bang: Physics Questions Are Effort's Focus*, BOSTON GLOBE, May 12, 2007, at 1A.

[29] Close, *supra* note 24.

[30] Nickerson, *supra* note 28.

[31] Dennis Overbye, *Fingers Crossed, Physicists Are Ready for Collider to Roll*, N.Y. TIMES, Sept. 9, 2008, at F2.

[32] Overbye, *supra* note 1.

[33] Dennis Overbye, *Ah Spring! Swallows, Baseball, Colliding Protons*, N.Y. TIMES, Sept. 24, 2008, at A7.

take place until the fall of 2009.[34] Meanwhile, scientists in the United States at Fermilab continue to work to "nose out" the LHC in its quest for the Higgs particle.[35]

This latest accident is the second major problem scientists at CERN have had involving failing magnets and leaking helium.[36] In the spring of 2007, an "elementary mistake" in the design of the magnets caused a large explosion, and helium leaked into the collider tunnel, forcing an evacuation.[37] The director of Fermilab, the American lab that built the magnets, said, " 'We are dumbfounded that we missed some very simple balance of forces. Not only was it missed in the engineering design but also in the four engineering reviews carried out between 1998 and 2002 before launching the construction of the magnets.' "[38] This accident, caused by basic mathematical error, has led some to question whether similar mistakes are present in other aspects of the LHC's construction or in its risk assessment, which might have "infinitely more dramatic consequences."[39]

It took fourteen years and $8 billion to build the LHC, so naturally scientists and other interested observers are eager to see what it can do.[40] Physicists around the world have high hopes for the machine, and anticipate that the LHC may "reveal the origins of mass, shed light on dark matter, uncover hidden symmetries of the universe, and possibly find extra dimensions of space."[41] Other scientists hope to observe "the near-instantaneous creation and decay of 'miniature' black holes; and perhaps even rips in the space-time fabric that will allow a peek into dimensions beyond."[42]

Not everyone has greeted the advent of the world's largest particle collider with the same excitement as much of the scientific community.[43] Certain

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[34] Dennis Overbye, *Officials Set Timetable for Getting Particle Collider Back on Track*, N.Y. TIMES, Feb. 17, 2009, at D3.

[35] *Id.*

[36] *Id.*; Leake, *supra* note 27.

[37] Leake, *supra* note 27.

[38] *Id.*

[39] Gerald Warner, *If You're Here to Read This, Perhaps All Is Well*, DAILY TELEGRAPH (U.K.), Sept. 10, 2008, at 21.

[40] Overbye, *supra* note 31.

[41] *Boston Physicists Celebrate First Beam for Large Hadron Collider*, J. TECH. & SCI., Sept. 28, 2008, at 269.

[42] Nickerson, *supra* note 28; *see also* Frank Wilczek, *Forecasting the Fate of Mysteries: Top Physicist Forecasts from Hawking, Greene and More*, NEWSWEEK, Sept. 15, 2008 (giving detailed predictions of what the LHC may reveal by world-renowned physicists).

[43] *See* Matthew Reisz, *Things that Go Bump in the Night*, TIMES HIGHER EDUC. SUPP., Sept. 4, 2008, at 36 (presenting the LHC experiment as only one of many scientific endeavors

theories proposed by a few scientists have given rise to concerns that the particle collisions at the LHC may produce some exotic physical phenomena that could have disastrous consequences for the planet.[44] Among the leading disaster theories are those such as earth-swallowing black holes and the transformation of all matter on earth into a super-dense glob of cosmic goo.[45] These concerns have been picked up by the mainstream media, resulting in sensationalist and apocalyptic headlines.[46] In some cases, fear of these disasters has led to hysterical reactions such as the suicide of a teenage girl in India[47] and death threats against scientists associated with the project.[48]

CERN has widely dispelled any suggestion that the LHC is dangerous, insisting that "whatever the LHC will do, nature has already done many times over during the lifetime of the Earth and other astronomical bodies."[49] To prove the safety of the LHC, CERN published its own official safety report in 2003, which discounted the possibility that the LHC could cause the destructive phenomena that many feared.[50] This report was followed by a second report authored by an anonymous Safety Assessment Group in January 2008, which also concluded that the LHC was completely safe.[51]

Despite CERN's reassurances and the overwhelming consensus of physicists about the safety of the LHC, some remain unconvinced that the LHC collisions should proceed. A few scientists were so concerned about the LHC that they took their claims to court to seek injunctions against the project.[52] Before addressing these lawsuits, it is important to understand the nature of the alleged disaster scenarios and the arguments for and against proceeding with the experiment.

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necessary to "bring us closer to a Grand Unified Theory of Physics, or a Theory of Everything").

[44] *Id.*

[45] *Id.*

[46] Michio Kaku, *The Big Bank Machine: Large Hadron Collider at CERN: The End of the World as We Know It?*, GUARDIAN (U.K.), June 30, 2008, at 16.

[47] *Girl Suicide 'over Big Bang Fear,'* BBC NEWS, Sept. 11, 2008, http://news.bbc.co.uk/2/hi/south_asia/7609631.stm.

[48] *The Controversial Search for the God Particle*, SPIEGEL ONLINE INT'L, Sept. 9, 2008, http://www.spiegel.de/international/europe/0,1518,577219,00.html.

[49] Reisz, *supra* note 43.

[50] JEAN-PAUL BLAIZOT ET AL., CERN, STUDY OF POTENTIALLY DANGEROUS EVENTS DURING HEAVY-ION COLLISIONS AT THE LHC: REPORT OF THE LHC SAFETY STUDY GROUP (2003), *available at* http://doc.cern.ch/yellowrep/2003/2003-001/p1.pdf [hereinafter LSSG REPORT].

[51] JOHN ELLIS ET AL., CERN, REVIEW OF THE SAFETY OF LHC COLLISIONS (2008), http://lsag.web.cern._ch/lsag/LSAG-Report.pdf [hereinafter LSAG REPORT].

[52] William Booth, *Smashing Idea: To Leap Forward, Scientists Return to the Big Bang*, WASH. POST, Sept. 11, 2008, at C1.

IV. STRANGELETS, BLACK HOLES, AND MONOPOLES, OH MY!

Four primary concerns have been advanced by LHC critics, all of which have been addressed in at least one of the official safety studies conducted by CERN. These four scenarios include production of strangelets, production of micro-black holes, production of magnetic monopoles, and the "vacuum bubble" scenario.[53] The next few sub-sections provide a layman's description of each of these phenomena and briefly describe some of the major arguments for and against these theories. A more thorough and technical treatment of the science behind these arguments is available in the articles listed in the footnotes.

A. Strangelet Disaster

Some scientists have hypothesized that a particle collision at the LHC might create a shower of sub-atomic particles called up, down, and strange quarks that could reassemble into a "hypothetical state of matter" called "strange quark matter" or "strange matter," consisting of roughly equal numbers of these quarks.[54] This strange matter could coalesce into a small lump, which instead of decaying into normal matter would form a "compressed object called a strangelet."[55] The strangelet would then convert anything it encountered into strange matter until it transformed "the entire planet Earth into an inert hyperdense sphere about one hundred metres across."[56]

In the 2003 report, the LSSG found no risk of a strangelet disaster.[57] The Safety Group acknowledges that there exists no "first-principles" theory of strange quarks or strangelets, which have only been studied within phenomenological models.[58] The report claims, however, that evidence from naturally occurring particle collisions, called cosmic-ray[59] collisions, is

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[53] LSSG REPORT, *supra* note 50, at iii; LSAG REPORT, *supra* note 51, at 1.

[54] LSAG REPORT, *supra* note 51, at 9.

[55] MARTIN REES, OUR FINAL HOUR: A SCIENTIST'S WARNING 120 (2003).

[56] REES, *supra* note 55, at 121; *see also* Frank Wilczek, *Big Troubles, Imagined and Real*, *in* GLOBAL CATASTROPHIC RISKS 346, 350–54 (Nick Bostrom & Milan M. Ćirković eds., 2008) (giving an in-depth discussion of the physics related to quarks and strangelets and reasons for excluding the possibility that they could be produced at the LHC).

[57] LSSG REPORT, *supra* note 50, at 1.

[58] *Id.* at 2.

[59] Cosmic rays are particles which travel through space at close to the speed of light and frequently collide into other atomic nuclei at greater energies than can currently be achieved by man-made particle colliders. LSAG REPORT, *supra* note 51, at 13; *see also* Merriam-Webster Online, Definition of Cosmic Ray, http://www.merriam-webster.com/dictionary/cosmic%20ray

impossible to collect.[60] Research from the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory in Brookhaven, New York also indicates the impossibility of producing a strangelet at the LHC.[61] However, the 2003 LSSG report states very forthrightly that none of the estimates about "production probabilities and subsequent properties of various objects at the LHC" are "absolutely assumption-free."[62] In the 2008 LSAG report, scientists reiterated the conclusions of the 2003 report and buttressed these arguments with further empirical evidence from experiments conducted at RHIC after publication of the 2003 report.[63] The physicists emphasized that based on the theorized properties of strangelets, the higher heat of LHC collisions would be less likely to produce a strangelet than the RHIC collisions.[64]

On the other hand, astrophysicist Dr. Martin Rees critiques the claim that the cosmic ray analogy proves the safety of particle colliders against strangelet disasters.[65] Rees points out that high-energy collisions that occur in space differ in some relevant respects from experiments which take place on Earth.[66] According to Dr. Rees, these differences might make a strangelet disaster more probable.[67] In particular, even if a cosmic-ray collision produced a strangelet,

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(last visited Nov. 6, 2009).

[60] LSSG REPORT, *supra* note 50, at 1.

[61] *Id.* at 1, 4–9.

[62] *Id.* at 2.

[63] LSAG REPORT, *supra* note 51, at 10–11.

[64] *Id.* at 12. The report analogizes the likelihood of the LHC producing a strangelet to "the likelihood of producing an icecube in a furnace." *Id.* at 11; *see also* JOHN ELLIS ET AL., CERN, REVIEW OF THE SAFETY OF LHC COLLISIONS: ADDENDUM ON STRANGELETS (2008), http://lsag.web.cern.ch/lsag/LSAG-Report_add.pdf (giving further support to LSAG's contentions that it would be less likely to produce a strangelet at LHC than at RHIC).

[65] Interestingly, Rees was one of the early proponents of the cosmic ray analogy in 1983 when he was visiting the Institute for Advanced Study in Princeton, where he used the analogy to validate the safety of particle collisions that were then taking place. REES, *supra* note 55, at 122–24. However, Rees notes that at the time, the assurance of safety was based on the then-existing accelerators, and he speculated that the "concerns would revive" if "these accelerators became a hundred times more powerful." *Id.* at 122.

[66] *Id.* at 123.

[67] *Id.* Rees also responds to a report published by Brookhaven Laboratory prior to the RHIC's commissioning that used the Moon as an example of a place where cosmic-ray collisions occur with heavier, more earth-like particles. *Id.* The Brookhaven scientists argued that because these collisions have occurred without a strangelet disaster for as long as the moon has existed, there would not be such a disaster at RHIC either. *Id.* Rees points out, however, a fundamental difference between collisions on the moon and ones produced in a collider: collisions of cosmic rays with the moon would send lunar particles "hurtling" through the moon, whereas particles in a collider approach each other at the same speed—thus, there is no net motion after their collision. *Id.* at 123–24. Rees says this may give a strangelet particle more opportunity to "grab"

it is very unlikely that the strangelet would encounter an additional nucleus in the vast expanse of outer space to allow the runaway process that is feared might occur on Earth.[68] Additionally, Rees points out that cosmic-ray collisions occurring in the earth's atmosphere would not involve heavy atoms like the lead or gold used in experiments on Earth, which may also be an "essential" difference.[69] While Rees has asserted that the experiments "didn't give [him] any sleepless nights," he states this attitude is "little more than [a] subjective assessment[ ]."[70]

Along a similar vein, Judge Richard Posner has directly addressed the claims of the LSSG report regarding the risk of strangelets in his book on catastrophic risk.[71] Posner critiques the "empirical evidence" of the lack of strangelet production at RHIC and argues that simply because there has never been a strangelet disaster, this "[does] not falsify the very low probabilities that the concerned scientists had assigned to such an event."[72]

Posner also critiques another aspect of the cosmic ray analogy cited by the LSSG report which says that if strangelets form in cosmic-ray collisions they would be " 'swept up in star formation and lead to the . . . destruction of the star' " in a supernova event.[73] Since supernovas are very rare events, it seems unlikely that cosmic ray collisions can create strangelets, according to scientists at the LHC.[74] Posner finds this argument unconvincing, because "the strangelet created by [a cosmic ray] collision might decay in less 'than the time it takes for it to be swept up into a [forming star]' " and thus supernovas would still be relatively rare.[75]

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other particles in a collider. *Id.* at 124. Thus, neither collisions in the earth's atmosphere nor on the moon's surface serve as completely accurate natural models of what will occur in the experiment. *Id.*

[68] *See id.* at 124 (quoting Theorist, Richard Glashow and environmental and energy expert, Richard Wilson).

[69] *Id.* at 123. However, Rees reiterates that the LHC's safety predictions are based on probabilities, not certainties, since it is not clear that these particle collisions have ever occurred under conditions identical to those at the LHC. *Id.* at 124–25.

[70] *Id.* at 124–25.

[71] RICHARD A. POSNER, CATASTROPHE: RISK AND RESPONSE 194 (2004).

[72] *Id.* at 195. Posner analogizes this to the probability of aircraft engine failure. *Id.* "If an aircraft engine were predicted to fail in only 1 out of 50,000 flight miles, the fact that the engine had run smoothly for the first 1,000 miles of flight would not require a reassessment of the odds . . . assigned beforehand." *Id.*

[73] *Id.* at 194 (quoting LSSG REPORT, *supra* note 50).

[74] *See id.* ("The authors of the study[,] . . . on the basis of the [rare] incidence of supernovas . . . produced the upper-bound estimate for a stangelet disaster at RHIC of 1 in 500 million per year.").

[75] *Id.* at 195 (quoting the LSSG REPORT, *supra* note 50).

B. Black Holes

LHC critics have also expressed concern that the collisions might produce miniature black holes which would then begin to suck in all matter around them, eventually destroying the earth.[76] The 2003 LSSG group addressed this scenario as well in its report, dismissing it as impossible.[77] According to the report, it is unlikely that the collider will produce a black hole, but if one does somehow form, it will decay so rapidly, through a theoretical process called Hawking radiation,[78] that it would pose no risk.[79] Additionally, the report states that in the event a stable black hole could be formed that does not decay, it would not be able to grow due to the properties of normal matter around it.[80]

The 2008 LSAG report bolsters the findings of the LSSG report with further analysis regarding Hawking radiation.[81] This argument is essentially the same as Rees's, namely that the same mechanism which would allow production of a black hole would also require it to dissipate virtually instantly.[82] Additionally, this report uses observations of neutron stars and cosmic rays to build the case that dangerous black holes will not occur at LHC.[83]

Several scientists have published papers alleging that production of stable and dangerous mini-black holes may still be possible at LHC. One such paper, published by German scientist Otto Rössler, reinterprets an old formula to show that a mini-black hole might not evaporate via Hawking radiation and may be able to accrete matter at a rate that poses danger to the earth.[84] Not

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[76] Even Dr. Rees dismisses this theory, noting that in the unlikely event a collider could create a black hole, the same processes that allow production of the black hole would also make it "erode" almost instantly before it did any damage. REES, *supra* note 55, at 120.

[77] LSSG REPORT, *supra* note 50, at 9–13.

[78] While the theory of Hawking radiation is widely accepted, it has never been observed and its existence has even been questioned on occasion. *See* Adam D. Helfer, *Do Black Holes Radiate?*, 66 REP. ON PROGRESS IN PHYSICS 943, 946–1005 (2003) (challenging the scientific assumptions underlying Hawking radiation); William G. Unruh & Ralf Schützhold, *On the Universality of the Hawking Effect*, 71 PHYS. REV. D 024028 (2005) (suggesting that the known relationship between black holes and Hawking radiation remains incomplete).

[79] LSSG REPORT, *supra* note 50, at 12.

[80] *Id.* at 12–13.

[81] *See* LSAG REPORT, *supra* note 51, at 7 (stating that "if microscopic black holes were to be singly produced[,] . . . they would also be able to decay into the same types of particles that produced them").

[82] *Id.* at 7–10; REES, *supra* note 55, at 120.

[83] *See* LSAG REPORT, *supra* note 51, at 9 (noting that "[t]he observation of white dwarfs and neutron stars . . . tells us that cosmic rays do not produce such black holes, and hence neither will the LHC").

[84] Otto E. Rössler, Abraham-Solution to Schwarzschild Metric Implies that CERN Miniblack

only has this theory been rejected by particle physicists associated with the LHC, but these physicists have ridiculed Rössler's understanding of the physics involved.[85]

Another German scientist, astrophysicist Rainer Plaga, also questioned the safety of the LHC with regards to dangerous micro-black holes. In his paper, Plaga does not question the occurrence of Hawking radiation, but instead purports to show how it might actually be dangerous and create an explosion similar to the detonation of a thermonuclear bomb at CERN.[86] Two highly respected particle physicists associated with the LHC project, Steven Giddings and Michelangelo Mangano, responded to this paper and alleged mistakes in Plaga's calculations, trying to disprove his theory.[87] Plaga responded to this paper with an addendum to his original work, claiming that Giddings and Mangano misunderstood his theory.[88]

This response went unanswered for several months until a different group of physicists released a paper that purported to respond to both the Giddings and Plaga papers.[89] This paper theorized that, based on an alternative view of physics, a stable miniature black hole could be created, but the authors concluded that such a black hole would exit the earth's atmosphere before it

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Holes Pose a Planetary Risk (Div. of Theoretical Chemistry, U. Tübingen) (Sept. 27, 2007), http://www.wissensnavigator.com/documents/ottoroesslerminiblackhole.pdf.

[85] *See* Domenico Giulini & Hermann Nicolai, On the Arguments of O.E. Rössler, at 1–2 (Aug. 2008), http://environmental-impact.web.cern.ch/environmental-impact/Objects/LHCSafety/NicolaiFurtherComment-en.pdf (noting that Rössler's argument "makes no logical connection to LHC physics").

[86] *See* Rainer Plaga, On the Potential Catastrophic Risk from Metastable Quantum-Black Holes Produced at Particle Colliders, at 5–9 (Aug. 10, 2008, version 1) [hereinafter Plaga, version 1] (noting that because "sufficiently stable [micro-black holes] might accrete matter at an extremely fast rate[,] . . . quasistable [micro-black holes] are potentially dangerous"). Plaga has since updated his paper twice in response to the critique of other scientists. See discussion *infra* pp. 142–144, 158–164 and accompanying notes. Access to all three versions of Plaga's paper can be found at http://arxiv.org/abs/0808/1415v1.

[87] Steven B. Giddings & Michelangelo L. Mangano, *Comments on Claimed Risk from Metastable Black Holes*, Aug. 29, 2008, http://arxiv.org/PS_cache/arxiv/pdf/0808/0808.4087v1.pdf.

[88] Rainer Plaga, On the Potential Catastrophic Risk from Metastable Quantum-Black Holes Produced at Particle Colliders, at 9–11 (Sept. 26, 2008, version 2) [hereinafter Plaga, version 2].

[89] Roberto Casadio, Sergio Fabi & Benjamin Harms, On the Possibility of Catastrophic Black Hole Growth in the Warped Brane-World Scenario at the LHC (Feb. 17, 2009), http://arxiv.org/PS_cache/arxiv/pdf/0901/0901.2948v2.pdf.

became dangerous.[90] Plaga, in an update to his earlier paper, argues that even using the authors' parameters there is some residual risk.[91]

A fourth paper has theorized, also on the basis of an alternative view of physics, that the LHC may be capable of producing a stable micro-black hole.[92] However, the authors do not say whether they believe such a black hole would pose any risk to the earth. This paper also appears to have gone unchallenged.

The fact that these last two papers have not been disputed raises some interesting questions. When Plaga released his paper arguing that the LHC might produce a dangerous mini-black hole, scientists associated with the project issued a reply paper in just under three weeks.[93] The Maia and Casidio papers challenge one of the primary assertions of the LSAG and LSSG reports, namely that it is not possible to produce a stable micro-black hole due to Hawking radiation, yet CERN has not directly responded to either of them.

There are at least three possible reasons why there has been no response to these papers: (1) the physics therein is accurate and plausible (2) the physics may not be accurate or plausible, but the papers reach the same conclusion as the LSAG and LSSG that the LHC is not dangerous, or (3) the LHC has already been started and those involved in the project believe that they do not need to challenge these theories to proceed with the project.

If the first reason is correct, the LSAG and LSSG either missed this scenario or purposely omitted it. This raises the somewhat disturbing possibility that the LSAG or LSSG may have omitted or missed other issues. If the second reason is correct, it shows a troubling tendency of the scientists involved in the project to only challenge those who believe the LHC might be dangerous. At the very least, this would indicate some level of intellectual dishonesty. Finally, if the third reason is correct, it shows a certain arrogance on the part of CERN that because the project has started, it no longer needs to defend the project's safety.

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[90] *See id.* at 8 (noting that the mass of the black hole would "remain[ ] at microscopic values," and thus "never reach[ ] catastrophic size before leaving the Earth").

[91] Plaga, version 1, *supra* note 86, at 14.

[92] *See* M.D. MAIA & E.M. MONTE, ON THE STABILITY OF BLACK HOLES AT THE LHC, at 3 (Aug. 19, 2008), http://arxiv.org/PS_cache/arxiv/pdf/0808/0808.2631v1.pdf (noting that "it is possible that . . . the behavior of black holes is stable").

[93] Plaga's initial paper was released on August 10, 2008. Plaga, version 1, *supra* note 86. Giddings's and Mangano's paper was released on August 29, 2008. Giddings & Mangano, *supra* note 87.

C. Magnetic Monopoles

A third concern of LHC skeptics is the production of magnetic monopoles, which are particles with a non-zero magnetic charge that might catalyze other particles in a reaction similar to the strangelet disaster.[94] The LSSG and LSAG reports discount this possibility, saying that it is unlikely the LHC collisions would have the requisite energy to create such a particle, and even if it did, the amount of matter such a "light proton-eating magnetic monopole[ ]"[95] could consume before exiting the earth's atmosphere is so small that it does not pose "any conceivable threat."[96] There do not appear to be any scientific papers asserting that the LHC still poses any sort of danger for producing a magnetic monopole disaster. Thus, the safety reports in this area are susceptible to criticism only due to the possible inapplicability of the cosmic-ray analogy discussed above with regard to the strangelet scenario.

D. Vacuum Bubble

A fourth major concern regarding the safety of the LHC involves a theorized phenomenon called a vacuum bubble.[97] The vacuum bubble problem is best described by Rees:

> Empty space—what physicists call "the vacuum"—is more than just nothingness. It is the arena for everything that happens: it has, latent in it, all the forces and particles that govern our physical world. Some physicists suspect that space can exist in different "phases," rather as water can exist in three forms: ice, liquid, and steam. Moreover, the present vacuum could be fragile and unstable. The analogy here is with water that is "supercooled." Water can cool below its normal freezing point if it is very pure and still; however, it takes only a small localised disturbance—for instance, a speck of dust falling into it—to trigger supercooled water's conversion into ice. Likewise, some have speculated that the concentrated energy created when particles crash together could trigger a "phase transition" that would rip the fabric of space itself. The boundary of the new-

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[94] LSAG REPORT, *supra* note 51, at 6.
[95] *Id.*
[96] LSSG REPORT, *supra* note 50, at 13.
[97] REES, *supra* note 55, at 121.

> style vacuum would spread like an expanding bubble. In that bubble atoms could not exist: it would be "curtains" for us, for Earth, and indeed for the wider cosmos; eventually, the entire galaxy, and beyond, would be engulfed. And we would never see this disaster coming. The "bubble" of new vacuum advances as fast as light, and so no signal could forewarn us of our fate. This would be a cosmic calamity, not just a terrestrial one.[98]

Though the LSSG report did not address the issue of vacuum bubbles, it was addressed in the 2008 LSAG report.[99] The LSAG group's primary defense to the vacuum bubble scenario is that "if LHC collisions could produce [such a phenomenon], so also could cosmic-ray collisions."[100] If cosmic-ray collisions could create vacuum bubbles then the "new vacuum" would have consumed "large parts of the visible Universe several billion years ago."[101] The fact that the universe still exists means that vacuum bubbles are not produced in cosmic-ray collisions, and therefore the LHC collisions will not produce them.[102]

Like the magnetic monopole scenario, there have not been any scientific papers challenging the LSAG or LSSG's position on this issue. Thus, the safety of the LHC experiment with regards to the vacuum bubble scenario could be challenged only on the basis of the cosmic-ray analogy.

V. SLAYING THE DRAGON OR TILTING AT WINDMILLS?: LEGAL CHALLENGES TO THE LARGE HADRON COLLIDER

As one might expect in a hotly contested dispute with such potentially dramatic consequences, critics of the project, unable to convince the scientific community of the veracity of their claims, took their concerns to court to enjoin the LHC experiments and effectively force the physics community to listen to their concerns.[103] While neither of these cases has been successful thus far, both provide an interesting look into the legal status of a group like CERN and how a court addresses such issues.

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[98] *Id.*
[99] LSAG REPORT, *supra* note 51, at 5.
[100] *Id.*
[101] *Id.*
[102] *Id.* at 5–6.
[103] Booth, *supra* note 52.

A. Practical Difficulties

1. CERN's Legal Status

There are some practical difficulties to bringing such a lawsuit. One of the most problematic issues is that of obtaining jurisdiction over CERN, given its unique legal status as an intergovernmental organization. CERN's organizing document, the Convention for the Establishment of a European Organization for Nuclear Research, signed in 1954 and amended in 1971, sets forth in Article IX that CERN's "legal personality" is in the "metropolitan territories of all Member States."[104] This article further provides for certain "privileges and immunities" to be negotiated by CERN and its member states, including the host countries of France and Switzerland.[105] Thus, because CERN exists as a legal personality in all its member states, it follows that suit may be brought in any of its member states, barring any agreement to the contrary.

Following the CERN Convention's signing, CERN executed two such agreements with its host states, Switzerland and France. CERN entered into an agreement with the Swiss Federal Council in 1955 that granted, along with several other privileges and immunities, immunity for CERN in Switzerland "from every form of legal process except in so far as this immunity is formally waived by [CERN] or its duly authorized representative."[106] CERN signed a similar agreement with France in 1972 asserting that CERN, "its property, funds and assets shall enjoy immunity from legal process, except in so far as this immunity is specifically waived in a particular case by the Director-General . . . or the person acting in his stead."[107] This agreement does specify that if CERN institutes legal proceedings, it is no longer immune from counterclaims in that case; however, the provision further states that waiving immunity to process "shall not imply waiver of immunity from the execution of judgment, which must always be waived separately."[108] To complete CERN's legal immunity, CERN introduced a new protocol in 2004, granting

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[104] CERN Convention, *supra* note 16, art. IX.

[105] *Id.*

[106] Agreement Between the Swiss Federal Council and the European Organization for Nuclear Research Concerning the Legal Status of that Organization in Switzerland art. 6.1, CERN-Switz., June 11, 1955, 249 U.N.T.S. 405.

[107] Agreement Between the Government of the French Republic and the European Organization for Nuclear Research Concerning the Legal Status of the Said Organization in France art. VI(1), CERN-Fr., June 16, 1972, 871 U.N.T.S. 216.

[108] *Id.* art. VI(2).

CERN immunity from legal process and execution of judgment in all of its member states.[109]

2. Cause of Action

In addition to such immunity, another difficulty in bringing this type of suit is specifying a cause of action. The essential legal theory behind such a suit would be that CERN is going to conduct a science experiment which may dramatically increase knowledge of the universe, but also that there is an extremely small, theoretical, yet non-zero chance this experiment may destroy the world. It is difficult to envision what body of law would apply to such a claim. As one group who filed suit stated in its complaint, there essentially is no such body of law.[110]

3. Preliminary Injunction as Relief

A related difficulty in bringing such a suit is in evaluating the claim for purposes of a preliminary injunction, which is commonly the relief prayed for. Professor Eric Johnson has addressed the difficulty of meeting this standard.[111] Johnson points to the serious difficulty of "balanc[ing] the hardships," given that these hardships may be characterized as stopping or seriously harming scientific progress, versus the slight possibility the world may be "devoured by a black hole."[112] As Professor Johnson surmises, at such extremes the balancing test behind a preliminary injunction "seem[s] to break down."[113]

Additionally, Professor Johnson notes it is useless to bring in expert testimony to assist in this evaluation because a *Daubert*[114] analysis, the mechanism for admitting this type of testimony, is similarly limited by the complex factors involved.[115] First, Professor Johnson points out that under *Daubert*, an expert's asserted theory must be "testable, falsifiable, and

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[109] Protocol on the Privileges and Immunities of the European Organization for Nuclear Research art. 5, Mar. 18, 2004, *available at* http://doc.cern.ch//archive/electronic/other/generic/public/cer-002693576.pdf. This immunity may, however, be waived by CERN. *Id.*

[110] *Rössler* Complaint at 51, *supra* note 7.

[111] Posting of Eric E. Johnson to Prawfs Blawg, http://www.prawfsblawg.blogs.com/prawfsblawg/2008/10/planet-eating-b.html (Oct. 21, 2008, 04:15 EST).

[112] *Id.*

[113] *Id.*

[114] Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579 (1993).

[115] Johnson, *supra* note 111.

refutable."[116] Yet in the present case, the theory itself is what is at issue, and the only way to test the viability of any theory is to activate the machine and see what happens.[117] Next, Johnson asserts that *Daubert* requires examination of the general scientific consensus regarding the expert witness's theory.[118] This factor is easily applied here, as the overwhelming majority of scientists are in favor of the project.[119] Yet, as with the issue of whether the theory is testable, consensus is a circular question, since the point of the suit is to challenge the majority of scientists on a specific theory.[120]

Though the potential pitfalls to particle-collider litigation are numerous, several cases have been litigated on the issue. While no case has been successful in stopping a particle collider's commissioning, these suits do give interesting insight into the question of a proper forum for brining such a case and how it might be handled.

B. The Suit Against the Relativistic Heavy Ion Collider

The LHC is not the first particle collider to face legal challenges to its start-up. In 2000, Walter Wagner, a former nuclear safety expert, and Luis Sancho, a science writer, filed a lawsuit in a New York federal court to halt the start-up of the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory in Long Island, New York.[121] In that lawsuit, Mr. Wagner and Mr. Sancho claimed that the gold ions being smashed together at RHIC would trigger a black hole or strangelet disaster.[122] This lawsuit was ultimately dismissed in 2001,[123] when the court stated that the plaintiffs' claims were too

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[116] *Id.*

[117] *See id.* ("The theories of Rössler and Plaga can only be confirmed through the obliteration of the court, the parties, and the planet.").

[118] *Id.*

[119] *See id.* (noting, however, that requiring scientific-expert opinion in this matter would be "tantamount to making consensus decisions of the scientific community on laboratory safety issues unsusceptible to judicial review").

[120] *Id.*

[121] Dennis Overbye, *Government Seeks Dismissal of End-of-World Suit Against Collider*, N.Y. TIMES, June 27, 2008.

[122] *See* Brief for Sheldon Glashow et al. as Amici Curiae Supporting Defendants at 8 n.6, Sancho v. Dep't of Energy, 578 F. Supp. 2d 1258 (D. Haw. 2008) (No. 08-00136HG KSC) (citing to the New York case and stating that similar claims were dismissed).

[123] Overbye, *supra* note 4.

"speculative."[124] Since the suit against RHIC was dismissed, the machine has been operating "without incident."[125]

C. Sancho v. U.S. Department of Energy

The first case against the LHC was *Sancho v. Department of Energy*, filed in the United States District Court for the District of Hawaii,[126] naming the U.S. Department of Energy, the Fermi National Accelerator Laboratory, the National Science Foundation, and CERN as defendants.[127] The suit was filed by Luis Sancho and Walter Wagner, the same plaintiffs who had filed suit to stop the RHIC collider.[128] In their suit, Plaintiffs alleged that the defendants failed to conduct a proper environmental assessment (EA) as required by the National Environmental Policy Act (NEPA) and that they did not provide an environmental impact statement (EIS) or a "finding of no significant impact" (FONSI).[129]

To understand the nature of the plaintiffs' legal theory in this suit, it is helpful to look briefly at NEPA. This statute requires that all federal agencies:

> include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on
> (i) the environmental impact of the proposed action,
> (ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,
> (iii) alternatives to the proposed action,

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[124] Overbye, *supra* note 121.

[125] *Id.* In 2005 scientists working with the RHIC reported that a fireball had occurred that bore some mathematical resemblance to a black hole; however, the occurrence was not deemed to pose any danger because "at these energies and distances gravity is not the dominant force in a black hole." Eugenie Samuel Reich, *The World's First Black Hole, at a Collider near You?*, NEW SCIENTIST, Mar. 19, 2005, at 16.

[126] Sancho v. U.S. Dep't of Energy, 578 F. Supp. 2d 1258, 1259 (D. Haw. 2008).

[127] Overbye, *supra* note 4.

[128] *Sancho*, 578 F. Supp. 2d at 1259.

[129] *Id.*; *see* Complaint ¶ 18, Sancho v. U.S. Dep't of Energy, 578 F. Supp. 2d 1258 (D. Haw. 2008) (No. 08-00136 HG KSC) (stating that even if the LSAG REPORT were to qualify as an EA or an EIS, it "has not been timely prepared in advance of anticipated start-up of LHC operations so as to give the plaintiffs meaningful opportunity to respond, and seek court intervention if necessary").

(iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and
(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.[130]

For actions that fall under NEPA, the implementing agency must prepare an EA to "determine the significance of the environmental effects and to look at alternative means to achieve the agency's objectives."[131] Once the EA is reviewed, the reviewing agency either requires an EIS or issues a FONSI.[132] The legislation requires the federal agency to prepare an EIS if the reviewing agency finds that the proposed action is "a major federal action significantly affecting the quality of the human environment."[133] If the reviewing agency finds "no significant environmental impacts projected to occur upon implementation of the action," the agency will issue a FONSI.[134]

Though not clearly spelled out in the complaint, the plaintiffs' contention seems to have been that a 1997 agreement between CERN, the U.S. Department of Energy (DOE), and the National Science Foundation (NSF), under which DOE and NSF would provide $531 million and construct two particle detectors for the LHC, should be subject to NEPA,[135] which would require an EA followed by an EIS or FONSI.[136] The plaintiffs also made miscellaneous allegations about the defendants' failure to provide the notice required by the sections of the Code of Federal Regulations relevant to the Council on Environmental Quality.[137]

Additionally, the plaintiffs invoked several international bodies of law, alleging the defendants had "failed to adhere to the requirements of the European Council's *Precautionary Principle* adopted in support of the *World Trade Organization*" and had failed to adhere to the *Risk Governance* section

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[130] The National Environmental Policy Act of 1969, 42 U.S.C. § 4332(C)(i)–(v) (2006).

[131] COUNCIL ON ENVIRONMENTAL QUALITY, A CITIZEN'S GUIDE TO THE NEPA: HAVING YOUR VOICE HEARD 11 (2007) [hereinafter CEQ CITIZENS GUIDE], *available at* http://ceq.hss.doe.gov/nepa/Citizens_Guide_Dec07.pdf.

[132] *Id.* at 12.

[133] *Id.* at 13.

[134] *Id.* at 12.

[135] Sancho v. Dep't of Energy, 578 F. Supp. 2d 1258, 1266–67 (D. Haw. 2008).

[136] CEQ CITIZEN'S GUIDE, *supra* note 131, at 12.

[137] Complaint ¶¶ 16–22, *supra* note 129.

of the European Commission's "Science and Society Action Plan."[138] The suit was dismissed on September 26, 2008 after the district court found that the DOE and NSF's involvement with the project did not constitute "major federal action" sufficient to trigger the requirements of NEPA and give the district court jurisdiction to hear the case.[139] The court had previously dismissed the part of the suit pertaining to the plaintiffs' claims under international law, stating that the United States was not bound by any of the laws cited.[140]

D. Rössler v. Switzerland

Professor Otto Rössler, a German chemist at the Eberhard Karls University of Tübingen, brought the second suit to stop the experiments at the LHC.[141] Originally, Rössler's group had attempted to file a suit in the Swiss courts, seeking an injunction against one of the contractors working on the project.[142] This suit was thrown out for lack of standing.[143] As a last resort, Rössler filed his suit in the European Court of Human Rights against twenty European countries that funded the LHC.[144]

The European Court of Human Rights is essentially the enforcement body of the European Convention on Human Rights (the European Convention), which grew out of the Universal Declaration on Human Rights of 1948.[145] The European Convention guarantees certain rights and freedoms to signatory states and their citizens, and those states whose rights are violated may bring the offending entity in front of the court for a remedy.[146] More recently, there has developed a right for individuals to challenge actions in violation of their rights under the European Convention.[147] In order to bring a claim before the ECHR,

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[138] *Id.* ¶ 23.

[139] *Sancho*, 578 F. Supp. 2d at 1268.

[140] *Id.* at 1260.

[141] *Rössler* Complaint at 15, *supra* note 7; Richard Ingham, *Collision Course*, COURIER MAIL (Austl.), Sept. 10, 2008, at 25.

[142] *Rössler* Complaint at 47, *supra* note 7, at 47.

[143] *Id.*

[144] *Id.* at 3; Richard Gray, *Legal Bid to Stop CERN Atom Smasher from 'Destroying the World,'* TELEGRAPH (U.K.), Aug. 30, 2008, *available at* http://www.telegraph.co.uk/news/worldnews/europe/2650665/Legal-bid-to-stop-CERN-atom-smasher-from-destroying-the-world.html.

[145] Eur. Ct. H.R., *Information Document on the Court, Doc. No. 1762893*, at 1 (2006), *available at* http://www.echr.coe.int/NR/rdonlyres/981B902-45A4-44C6-829A-202A51B94A85/0/ENG_Infodoc.pdf.

[146] *Id.*

[147] *See id.* at 2 (stating that the adoption of Protocol No. 11 in 1998 required Contracting

one must allege, as the plaintiffs did, that he has exhausted all remedies in his home state and there is no other international law to which he can appeal.[148] Thus, the ECHR essentially functions as a court of last resort for those individuals whose fundamental rights are violated under the European Convention.

Rössler's suit sought a preliminary, emergency injunction to stop the start-up of the LHC, alleging the experiment "violat[ed] the right to life and right to private family life under the European Convention of Human Rights."[149] Rössler and his colleagues provided extensive scientific evidence about the risks they believed were involved, and argued that the threat posed by the LHC violated their right to life.[150] Additionally, they argued that court precedent and the European Convention allowed the court to intervene immediately where the "right of life" violation might be irreversible.[151] Finally, Rössler argued that the court's jurisdiction to protect his rights under the European Convention superseded the private contract granting CERN immunity.[152] This would mean that if the court found in Rössler's favor, the member states of CERN would be required to intervene and stop the LHC. While the court denied the petition for a preliminary injunction, it has allowed the substance of the suit to proceed.[153] It may be a very long time, though, before the suit will be heard on its merits, and, as Rössler argues, it will possibly be too late.[154]

E. The Future of Particle-Collider Lawsuits

These cases vividly illustrate the difficulty of bringing a suit when the danger is highly speculative, yet potentially catastrophic, and the entity responsible for the danger is hard to reach through legal process. First, as seen in the RHIC case, it is difficult for a plaintiff to prove that there is a danger when relying solely on theoretical physics. Even scientists in favor of the experiments can only offer probabilities of what will or will not happen. Dr.

States to recognize "the right of individual petition" under the European Convention).

[148] *See Rössler* Complaint at 47, 51, *supra* note 7.

[149] Gray, *supra* note 144. *See* Convention for the Protection of Human Rights and Fundamental Freedoms arts. 2, 8, Nov. 4, 1950, 213 U.N.T.S. 221 (providing in Article 2, "Everyone's right to life shall be protected by law," and in Article 8, "Everyone has the right to respect for his private and family life, his home and his correspondence").

[150] *Rössler* Complaint, *supra* note 7.

[151] *Id.* at 43–46.

[152] *Id.* at 47 (noting civil immunity and continuing the argument for jurisdiction).

[153] Gray, *supra* note 144.

[154] *See* Warner, *supra* note 39 (reacting to the ECHR spokeswoman, stating the case against CERN could "take several years").

Martin Rees describes these probabilities as an "informed guess" that may change as more information comes to light.[155] Rees says, "[w]hen physicists contemplate an event that has never happened before, or a process that is poorly understood, any assessment they can offer resemble[s] . . . an informed guess, buttressed (often very strongly) by well-established theories but nonetheless open to revision in light of new evidence or insight."[156]

In this light, this dispute amounts to a sort of zero-sum game. Either the particle collider is safe and there is nothing to worry about, or the particle collider will destroy the world and the plaintiffs (along with everyone else in the world) will suffer an irreparable harm. A court is thus put in the difficult position of deciding whether to issue an injunction based on highly speculative theories that would normally be insufficient for an injunction, or take the risk that such a speculative theory is correct and the world will be destroyed.

These cases also represent the unique challenge involved in litigating such an infrequent event. Particle colliders are phenomenally expensive, take years to construct, and are usually the product of international cooperation, as in the case of the LHC. There is little chance for plaintiffs to develop much case law on the issue, since they are often struggling to find the correct jurisdiction and body of law under which to sue. The LHC cases show the trial and error involved in fighting such an experiment. Finally, delays in the legal process and murkiness in this area of law mean that often, by the time a plaintiff can get his or her case in the right court with the right legal theory to have it heard on the merits, the case will likely be mooted by the experiment having proceeded in the meantime.

It is unlikely that RHIC and the LHC will be the last particle colliders to face legal obstacles. As physicists world wide continue to push the envelope by seeking to collide particles at ever higher energies, future conflicts may arises. There are plans for another powerful collider, the International Linear Collider (ILC), which will "complement" the collisions now being done in the LHC.[157] Physicists working on the project say the collider will be twenty miles long, and will collide electrons with their opposite particles, positrons, at energies of up to 500 billion geV in the first phase.[158] The project could be

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[155] Rees gives an example of this type of probability as being similar to a police investigator saying that it "seems very probable" that a body is buried in a particular place. REES, *supra* note 55, at 118–19. As he notes, "[f]urther digging will reveal that the body either is or isn't there, and the probability is thereafter either one or zero." *Id.* at 119.

[156] *Id.*

[157] Dennis Overbye, *The Big Bang and the Bucks Set to Collide in Inner Space*, N.Y. TIMES, Feb. 9, 2007, at A11.

[158] *Id.*

expanded to thirty-one miles in length and boosted to energies of a trillion eV in the second phase.[159] Scientists are currently deciding between sites at CERN near Geneva, Switzerland; the Fermi National Accelerator Laboratory in Batavia, Illinois; and in the mountains of Japan.[160] The project is expected to cost at least $6.7 billion.[161] Given the antipathy which has met the start-up of RHIC and the LHC, it seems likely that the ILC will face similar opposition.[162]

VI. FILLING IN THE "BLACK HOLE" OF PARTICLE-COLLISION REGULATION

While the overwhelming majority of physicists in the world seem content, based on the current understanding of physics, that the LHC experiments will not cause one of the catastrophic events discussed above, it seems that people on both sides of the LHC controversy can agree on at least one thing: no one is absolutely sure what will happen at the LHC experiments and there are some very frightening, but highly speculative, theories. As seen in the discussion above, court systems throughout the world are ill-equipped, at best, to deal with such issues. This brings up the interesting question of what, if anything, should be done about this situation.

A. Maintaining the Status Quo

One obvious solution would be to simply leave matters as they are, effectively allowing scientists to self-regulate and individual plaintiffs to blindly fish around for causes of action and venues to challenge these experiments. There are at least a few reasons, given the stakes if physicists are wrong, why this area of research should not simply be left to the scientists.

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[159] *Id.* This experiment differs from the LHC in that, like the LHC's predecessor the LEP, the ILC will collide electrons and positrons, rather than heavy protons. Scientists say that proton collisions are often "messy" and "wasteful" because of the many constituent parts which make up protons, such as quarks and gluons. *Id.* Electrons and positrons, on the other hand, have no such "innards, their collisions are cleaner, so they can be used to create and study with precision whatever new particles are found at CERN." *Id.* Collisions of electrons and positrons at an acceleration of 500 GeV and a total energy of 1 TeV would be five times more powerful than the energies reached in the electron-positron collisions at LEP in the 1990s. Battersby, *supra* note 23, at 40.

[160] Dennis Overbye, *The Next Big Thing in Physics is Huge and Costly*, INT'L HERALD TRIB., Feb. 9, 2007, at 2.

[161] *Id.*

[162] *See id.* (noting that "until the [LHC] proves its worth by actually finding something new, the governments of the world are unlikely to agree to contribute their share of the billions").

First, there are historical analogues which reveal that scientists are not always as cautious as some might hope about very speculative but very disastrous dangers. Prior to the first test of the atomic bomb during the Second World War and the test of the first hydrogen bombs in the 1950s, there was concern that the nuclear explosion might "ignite all the world's atmosphere or oceans."[163] Scientists working on the project made some "quick calculation[s]" and ultimately determined that there was not a significant risk of the aforementioned catastrophe.[164] As it turns out, based on today's scientific knowledge, these tests were safe (or as safe as a nuclear explosion can be) because detonating a single nuclear weapon "cannot trigger a nuclear chain reaction that would utterly destroy Earth or its atmosphere."[165] However, one might reasonably ask, "how small the contemporary estimates . . . would have needed to be before those in charge would have felt it prudent to abandon the H-bomb tests."[166]

Second, there are reasons to suspect that deferring to the "technocracy" of particle physicists to make these safety decisions is unwise because they may not be entirely objective about their projects. While LHC apologists point to the objectivity of the scientific method and the deliberative standards to which scientific theories are held, these things may not be enough to ensure the safety of the experiments. As one scholar has noted:

> If there is enough talk, some take it as a matter of faith that the public interest will emerge.
>
> There are a number of reasons to be agnostic if not atheistic about deliberation. Most fundamentally, there is little reason to believe that people with substantial, long-term, material interests in achieving a particular outcome are going to abandon those interests and their dedication to those outcomes as sweet reason emerges from the talk fest.[167]

This issue of objectivity is a very real problem particularly in the realm of particle physics, given that the majority, if not all, of the people who can

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[163] REES, *supra* note 55, at 117.

[164] *Id.*

[165] *Id.* at 118.

[166] *Id.* at 117.

[167] Martin Shapiro, *"Deliberative," "Independent" Technocracy v. Democratic Politics: Will the Globe Echo the E.U.?*, 68 L. & CONTEMP. PROBS. 341, 350 (2005).

understand these issues are involved in the project or have theories which they hope will be proven by the project.[168]

B. Towards a New International Regulatory Regime

Given the difficulties of addressing this area of scientific research through the courts and the fact that it may not be entirely safe to leave scientists to self-regulate, it seems this area is ripe for external regulation. It goes almost without saying that given the international scope of the possible threat and the international nature of the organizations posing the threat, such regulation would necessarily have to be international.

1. Science Courts

There are several possible ways to achieve this sort of regulation. One such way would be creation of a judicial or quasi-judicial body that could handle this type of case. This idea has been proposed before as a "science court" composed of specially trained jurists or in some proposals, scientists, to render decisions.[169] Some such adjudicative systems are in place already, such as the Maryland Business and Technology Case Management Programs, which "require each Maryland circuit court . . . to designate three specially trained judges for [its] business and technology track."[170] Additionally, the United Kingdom and Japan have specialized courts to handle patent cases with the assistance of scientific specialists.[171] Finally, France employs civil servants with special scientific training to handle certain science-related judicial issues.[172]

A specialized court system or tribunal is certainly a compelling solution to the problem of regulating potentially dangerous science experiments like the LHC. A science court would at the very least provide a clear venue in which to bring certain science-related cases. A science court, though, particularly an international one, would require some body of scientific law to guide it in rendering decisions. There does not appear to be such an all-encompassing system as of yet.

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[168] *See* POSNER, *supra* note 71, at 133 (noting that those involved "have professional or pecuniary stakes (or both) in such projects . . . and hence an incentive to downplay risks").

[169] *See id.* at 210–11 (discussing the idea of a science court and the way it would function as well as the purpose it would serve).

[170] *Id.* at 211.

[171] *Id.* at 213.

[172] *Id.*

Additionally, as Judge Posner recognizes, there would still be a certain amount of uncertainty in defining the jurisdiction of such a court, to determine whether it would address all "scientific issues" or just cases involving "catastrophic risks."[173] This would likely lead to "endless haggling" over whether certain jurisdictional triggers were met.[174] If a court were designed specifically to address catastrophic risks, for example, there could be some primary difficulty in defining "catastrophic risk." Further, it would be hard to determine when this trigger is met, given that experiments like the LHC involve highly speculative theories which resist easy quantification into "risk." These jurisdictional disputes will require more money from already expensive projects, slow or halt progress on these projects, and possibly result in an overall chilling effect on certain types of scientific research. Thus, while a "science court" does provide solutions to the problems of expertise and venue for these types of cases, it is still susceptible to some of the problems facing existing courts.

2. International Regulatory Regimes

It seems that whether or not one believes a science court is the right approach to a governing body, what is most needed is some set of guidelines or rules to govern these particle collision experiments.[175] It is interesting to note, as did LHC critic Dr. Rainer Plaga, that the current experiment is lacking in regulatory safety measures, and that future experiments may be similarly lacking.[176]

In contrast, other areas of science do have a certain amount of regulation of scientific research methods.[177] One example of such regulation is in the area of genetic engineering and biotechnology with the Council of Europe's Convention for the Protection of Human Rights and Dignity of the Human Being with Regard to the Application of Biology and Medicine.[178] This treaty

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[173] *Id.* at 210.

[174] *See id.* (explaining the difficulty in deciding whether a case would proceed to the science court).

[175] *See* Gerald Warner, *We Must Be Wary of Scientific Research*, TELEGRAPH (U.K.), Dec. 22, 2008, *available at* http://www.telegraph.co.uk/comment/telegraph-view/3562044/We-must-be-wary-of-scientific-research.html (stating that "[i]nternational law needs to wake up to the scientific challenges of the 21st century").

[176] Rainer Plaga, On the Potential Catastrophic Risk from Metastable Quantum-Black Holes Produced at Particle Colliders, at 11–12 (Aug. 9, 2009, version 3) [hereinafter Plaga, version 3].

[177] *Id.* at 12.

[178] Convention for the Protection of Human Rights and Dignity of the Human Being with Regard to the Application of Biology and Medicine, *opened for signature* Apr. 4, 1997, Europ.

imposes a duty on each signatory state to enact laws that will give effect to the terms of the treaty.[179] The treaty is aimed at preventing experimentation in biology and medicine that "may lead to acts endangering human dignity."[180]

In addition to treaties governing scientific experimentation, several treaties are designed to regulate activities with dramatic global effects. One of the best known of these treaties is the United Nations Framework Convention on Climate Change (UNFCCC)[181] and its well-known Kyoto Protocol.[182] The UNFCCC is aimed at achieving "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[183] To achieve this goal, the signatory states commit to reducing carbon emissions levels, with developed countries agreeing to the highest percentage reductions.[184] The Kyoto Protocol adds a level of enforcement to these commitments by requiring countries who do not meet their target for emissions reduction to reduce their emissions by an additional thirty percent and by suspending them from trading emissions credits.[185]

In addition to treaties that govern scientific experimentation and human activity, there is a third type of treaty that governs scientific experiments posing worldwide dangers. An example of such a treaty is the Comprehensive Nuclear-Test-Ban Treaty (CTBT), which governs the darker side of particle physics—nuclear weapons technology.[186] The CTBT prohibits the detonation of nuclear bombs for purposes of testing nuclear technology.[187] The CTBT takes a different approach to treaty enforcement by creating an international organization to oversee compliance.[188] Signatories who violate the treaty may

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[179] *Id.* ch. I, art. 1.

[180] *Id.* pmbl.

[181] United Nations Framework Convention on Climate Change, May 9, 1992, 1771 U.N.T.S. 107 [hereinafter UNFCCC].

[182] Kyoto Protocol to the United Nations Framework Convention on Climate Change, *opened for signature* Mar. 16, 1998, 2303 U.N.T.S. 148 [hereinafter Kyoto Protocol].

[183] UNFCCC, *supra* note 181, art. 2.

[184] *Id.* art. 4.

[185] United Nations Framework Convention on Climate Change, An Introduction to the Kyoto Protocol Compliance Mechanism, http://unfccc.int/kyoto_protocol/compliance/introduction/items/3024.php (last visited Nov. 8, 2009).

[186] Comprehensive Nuclear-Test-Ban Treaty art. I, *opened for signature* Sept. 24, 1996, 35 I.L.M. 1439.

[187] *Id.*

[188] *See id.* art. II, ¶ A (creating the Comprehensive Nuclear Test-Ban Treaty Organization as the implementing body).

lose any privileges granted thereunder, including access to monitoring information, and may be subject to sanctions or other penalties in accordance with international law.[189]

These treaties show the range of possibilities that exist for crafting an international regulatory regime to address the issue of particle collisions. Additionally, they at least show that there is precedent in international law of cooperation in regulating scientific activities with dramatic global effects. As a threshold matter, the aim of such regulation should not be to eradicate physics experimentation, as compared to the CTBT, whose aim is to eliminate nuclear weapons testing.[190] Particle physics experiments have resulted in some major scientific breakthroughs that have benefitted humanity.[191] However, given the potential danger of the LHC and its lack of an immediate goal to create any outcome for human application, it "should meet very stringent safety requirements."[192]

The first question in designing a regulatory scheme to govern particle collision experiments is what type of regulations should be required. Dr. Plaga, the previously-discussed astrophysicist and LHC critic, has offered some risk mitigation steps in his paper on the possibility of stable micro black hole production at the LHC.[193] First, he recommends increasing the energy of the particle collisions at smaller intervals than is currently planned by CERN, whose initial runs of the LHC are supposed to proceed at levels five times higher than previously reached.[194] As Plaga states, proceeding with CERN's plan "might result in the copious production of completely novel states, which production was exponentially suppressed at the previous energies."[195] Increasing the collision energy at smaller intervals will reduce this risk to some extent.[196]

Dr. Plaga also sees a problem with CERN's plan to only record and analyze 10^-7 of the events that occur during the particle collisions.[197] Dr. Plaga likens CERN's plan to that of "entering new territory . . . on the lookout only for the interesting but not the potentially dangerous," and he recommends that all

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[189] *Id.* art. V.

[190] *Id.* pmbl.

[191] John van Radowitz & Sam Marsden, *Hadron Collider: End of the World as We Know It?*, PRESS ASS'N, Sept. 10, 2008.

[192] REES, *supra* note 55, at 131.

[193] Plaga, version 3, *supra* note 176, at 11–12.

[194] *Id.* at 11.

[195] *Id.*

[196] *Id.*

[197] *Id.*

events during the collisions be recorded and analyzed.[198] Finally, Plaga suggests the implementation of measures designed to ensure reliable and immediate detection of micro black hole formation, and prompt shut-down and study of the event upon detection.[199]

Plaga's proposals provide a good starting point for developing a regulatory scheme to govern particle collisions and, at the very least, give some general principles that should govern such a scheme. These principles, to the average person, would seem fairly reasonable: proceeding slowly into unknown territory, constantly analyzing all the data from the particle collisions, and shutting down the experiment if something potentially dangerous appears.

These proposals strike a fair balance between encouraging scientific progress and ensuring safety. Since this scheme allows particle research to proceed, it avoids the severe chilling effect that might result from prolonged court battles or a court-ordered injunction. At the same time, the scheme puts some control over the safety of the experiments in the hands of people outside of the narrow group of interested persons in the scientific community. That a wider sector of the population should have control over the safety of these experiments seems fair, given that these projects are supported almost entirely by public funding.[200]

Despite the seeming reasonableness of Plaga's suggestions, they have been generally ignored by CERN scientists. Physicists Steven Giddings and Michelangelo Mangano, both involved in the project at CERN, reviewed Plaga's paper and issued a rebuttal paper.[201] This rebuttal attacked Plaga's calculations and claimed that his paper did not support the claim of a credible risk from micro black holes; however, the paper did not address any of Plaga's safety proposals.[202] In response, Plaga issued an updated version of his paper, in which he address the critique of Giddings and Mangano and purports to show the continued validity of his claim.[203] In this second paper, Plaga again urged CERN to implement his three proposed safety regulations, noting, as discussed above, that "[m]ethodologically similar measures have been taken in other areas of fundamental research under analogous circumstances, e.g. in

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[198] *Id.*

[199] *Id.*

[200] Posting of Euan MacDonald to Global Administrative law, GAL-and the End of the World as We Know It, http://globaladminlaw.blogspot.com/2009/01/global-administrative-law-and-end-of.html (Jan. 20, 2009, 13:47 EST).

[201] Giddings & Mangano, *supra* note 87, at 2.

[202] *Id.*

[203] Plaga, version 2, *supra* note 88, at 9–11.

biotechnology."[204] To date, CERN has not responded to Plaga's second or third papers or to his request for additional safety measures.

CERN's decision to ignore Plaga's suggestions for enhanced safety measures is hardly surprising, particularly since CERN's immunity agreements make them de facto a law unto themselves.[205] This situation reveals that the second key component of any proposed safety regime must be a compliance mechanism. Since the capital for projects like the LHC comes from CERN's member states and other interested parties,[206] the most logical means to ensure compliance would be to link the safety measures to project funding. Given the cost of these projects, it is extremely unlikely that any one country would build such a project without some outside support,[207] meaning that future colliders will likely be built either by CERN or by a similar coalition.[208]

Such a compliance mechanism could take the form of a clause that provided a contributing member state the right to cease contributions and receive an automatic injunction against the project if CERN or another such organization failed to comply with the safety measures in the regulatory scheme. An injunction could be granted by the International Court of Justice (ICJ), since CERN's charter already submits CERN to the ICJ's jurisdiction in the event of a dispute between members.[209] Additionally, there could be a second provision subjecting citizens of signatory states to civil liability in the form of statutory damages, criminal liability, or both for violation of the terms of the regime or the injunction.

It is probably more helpful to play out such a hypothetical dispute than to discuss it in the abstract. Assume that a new collider, the ABC, was built by CERN. When soliciting funds for this project, CERN informed all member states that any experiments at the ABC would be in compliance with a regulatory scheme similar to the one discussed above. The month prior to the experiments taking place, CERN announces that, in the interest of saving time and money, it will be performing the collisions at five times greater power than

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[204] *Id.* at 9.

[205] *See* MacDonald, *supra* note 200 (noting that "[s]hort of military action . . . it is difficult to see [how] a foreign court could . . . have its judgment enforced. CERN activities . . . do not themselves require the mediation of national actors in order to be effective.").

[206] Chris Llewellyn Smith, *How the LHC Came to Be*, 448 NATURE 281, 282 (2007).

[207] *See id.* (noting that, leading up to the development of the LHC, some of CERN's member states were "very unlikely to agree [to] a budget increase").

[208] *See id.* at 284 (noting that in the future, new projects "should, if possible, be sited at existing laboratories," and stating all cautions for the future in terms of "partners" and "international organizations," not individual countries).

[209] CERN Convention, *supra* note 16, art. XI.

had ever been attempted, instead of only two times as much as required in the regulatory scheme. Member State *X* immediately sues in the ICJ for an injunction against the project until such time as CERN complies with the safety regime. Since the safety terms say that new experiments may only be twice as powerful, and this new experiment is five times as powerful, Member State *X* would be entitled to an injunction. The threat of statutory damages or criminal liability would deter the scientists working at CERN from taking any sort of rogue action and proceeding with the experiment.

This hypothetical scenario illustrates several advantages of such a regulatory regime. First, it likely would avoid CERN's immunity agreements, which pose a problem for bringing a case against CERN in one of its member states. As discussed above, CERN's organizational agreement creates its legal personality in its constituent member states, and submits jurisdiction for disputes between member states to the ICJ. It should be noted that any injunction issued would have to be issued against the other member states themselves, since only states can be parties before the ICJ.[210] However, an injunction against the other member states' and their citizens' participation in the collision experiment would effectively shut down the experiment until it complied with the regulatory agreement.

An alternative approach would be to simply have CERN adopt the safety measures of the regulatory scheme. While CERN may be reluctant to do so at first, if it becomes clear that refusal may affect its ability to get funding, it will essentially have no choice. While this may seem like an overly harsh approach, as mentioned previously, the fact that CERN is almost exclusively using public funding would seem to imply that when it comes to safety, the public should have some say in how experiments proceed.

The hypothetical situation previously discussed also solves the problems posed by murky balancing tests. Instead of a judge having to decide whether some highly-speculative disaster scenario outweighs some uncertain scientific gains, the judge simply decides whether the scientific organization violated a set of safety regulations. If it did, then an injunction should issue. This type of decision making is much more in the realm of what jurists are used to dealing with and is more concrete than the abstract concepts that come up in these debates.

As a final note, the goal of such regulation is not, in any way, to vilify scientists or organizations like CERN. These groups add immeasurable value to humanity and their work should be encouraged. These regulations are merely intended to ensure that this work is carried out safely. This is one of the

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[210] Statute of the International Court of Justice ch. II, art. 34, June 26, 1945, 3 Bevans 1179.

major benefits of regulation versus judicial action. Judicial action tends to be an all-or-nothing approach: either the experiment will be allowed to proceed or it will not. Regulation, on the other hand, allows experiments to proceed but in a more gradual and safe manner. Every effort should be made to recruit and include particle physicists in the formulation of these "best practices" for the field. The drafters of this regulation could look at analogues in industry and other fields of science to determine safe standards that have worked in those areas.[211] Plaga's suggestions seem like a good and common-sense set of initial proposals, but there are certainly further standards which should be applied.

VII. CONCLUSION

This Note has addressed the history of particle colliders at CERN, the surrounding controversy, and the potential threats posed by these experiments. Additionally, it has looked at legal efforts to stop these experiments and the difficulties of bringing lawsuits to stop particle-collision experiments. Finally, it has proposed the possibility of a regulatory framework and has shown at least two key components of such future regulation. Further research is needed to address other issues that might keep such regulation from becoming a reality.

Particle physics is only one area of science that may pose risks to the future of humanity. As with particle physics, advances in the fields of nanotechnology and genetics have tremendous promise for improving people's lives. However, these fields also carry possible risks with equally devastating effects. As man's curiosity and thirst for knowledge continues unabated, there will continue to be a debate over how technological growth should be controlled and who will control it. Our desire to improve our quality of life must not become so consuming that we destroy the very thing we set out to improve.

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[211] Looking at other fields for guidance is exactly what is proposed by Dr. Plaga. Plaga, version 2, *supra* note 88, at 12.