On Monuments and Scientific Revolutions

Joseph D. Martin
Durham University, Department of History

Revolutions topple monuments. In Imperial Rome, the ousting of a particularly reviled emperor would be accompanied by the "*damnatio memoriae*," the erasure of the public image of a hated despot, including the destruction of statuary.[1] Within days of the United States' Declaration of Independence in July 1776, a gilded statue of King George III in New York had been torn down, its head and body disfigured.[2] And the #BlackLivesMatter protests that erupted in response to the May 2020 murder of George Floyd in Minneapolis, Minnesota, felled many monuments, among them a statue of the slave trader Edward Colston in Bristol (figure 1). Such acts are symbolic, but they also aim to create space into which new values, ideals, and practices can move. Most revolutionaries aren't driven by lust for destruction; they have strong ideas about what should go on those empty plinths. When we see a monument being toppled—whether acting as historians or as citizens—we should scrutinize the values, ideals, and practices the monument embodied, but we should also ask ourselves what the people doing the toppling would like to erect in its place.

Here, I apply this way of thinking to attacks on *scientific* monuments, addressing two

Figure 1. An empty plinth in Bristol, UK, where a statue of the slave trader Edward Colston stood before being toppled by protesters on 7 June 2020. *Credit*: Photo by Caitlin Hobbs, reproduced under CC BY 3.0, courtesy of Wikimedia Commons.

[1] Peter Stewart, "The Destruction of Statues in Late Antiquity," in *Constructing Identities in Late Antiquity*, ed. Richard Miles, 159–89 (London: Routledge, 1999). *Damnatio memoriae*, meaning "condemnation of memory," is a modern coinage.
[2] Holger Hooke, *Empires of the Imagination: Politics, War and the Arts in the British World, 1750–1850* (London: Profile Books, 2010), 50–51.

revolutions in twentieth-century physics.[3] The first is the revolution in high energy physics that led to what is known as the standard model, which describes elementary particles and forces governing them. High energy physics underwent a conceptual revolution after World War II. It proposed a radically revised understanding of microphysics; but revolted against what some saw as the pernicious effects of nuclear weapons, which cast a monumental shadow over the American physics community. The research programme that resulted was carried out using the iconic machines of big physics, particle accelerators that grew in size and expense as the century wore on.

But big physics generated a backlash. The second revolution I consider sought to topple the monuments of big science, arguing that they consumed too many resources for too little payoff, and that the reductionist worldview they encoded devalued other forms of knowledge. By seeking to distance physics from politics, these revolutionaries suggested, high energy physics had become political in another sense, forcing a confrontation with questions about why societies do and should support scientific research.

Making Physics Remote

On August 6, 1945, a uranium bomb codenamed *Little Boy*, dropped from an American B-29 Superfortress, detonated over the Japanese city of Hiroshima. Tens of thousands of people, mostly civilians, were killed almost instantly. Tens of thousands more later suffered from, or succumbed to, injuries sustained in the blast, including the effects of the bomb's radiation. Three days later, a plutonium bomb codenamed *Fat Man* wrought similar destruction on Nagasaki. Japan surrendered.[4]

The United States had announced nuclear weapons to the world, bringing physicists new and unfamiliar notoriety. Through the 1930s, physicists had painstakingly investigated the structure and behaviour of the atomic nucleus, labouring mostly in popular obscurity. Even in 1944, the president of the American Physical Society could remark, "It is a rare occurrence that a census taker has ever heard of a physicist, and the task of explaining is such that one is often tempted to register as a chemist."[5] The bomb, however, positioned physicists as custodians of an awesome power with the potential to reshape the global order.

Some embraced the bomb. Most notoriously, the Hungarian émigré Edward Teller championed an arsenal of bigger, more powerful weapons, which he hoped could be used for applications ranging from nuclear deterrence to carving out a new harbour in Alaska.[6] Others took a less hawkish approach, seeking to subjugate nuclear weapons to responsible, civic-minded custodianship. J. Robert Oppenheimer, the head of scientific operations at the Los Alamos laboratory where the bombs were assembled, advocated for international control of nuclear weapons, and, when that failed, sought to use his influence to rein in the excesses of Teller and his allies. Oppenheimer's scepticism of an expanded nuclear arsenal contributed to the Atomic Energy Commission's (AEC) revocation of his security clearance, over

[3] The term "revolution" is a fraught one for historians and philosophers of science. It is associated both with *the* Scientific Revolution of the seventeenth century, and debates over how revolutionary it actually was—see Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996)—and with Thomas Kuhn's *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962), the central and controversial contention of which was that science progresses through radical conceptual shifts, which lead scientists to adopt new worldviews incommensurable with those that grounded the old, abandoned theory. Here, I use the term in a different sense, one much closer to the notion of political revolutions, to refer to active efforts to change the organization and power structure of the scientific community.

[4] The bomb prompted Japan to accept the United States' unusual demand of unconditional surrender. The necessity of using the bomb to end the war in the Pacific has however been forcibly challenged. See Gar Alperovitz, *The Decision to Use the Atomic Bomb* (New York: Alfred A. Knopf, 1995).

[5] Albert W. Hull, "The Outlook for the Physicist and Prospective Physicist in Industry," *American Journal of Physics* 12 (1944): 62–70, on 66.

[6] Dan O'Neill, "Alaska and the Firecracker Boys: The Story of Project Chariot," in *The Atomic West*, ed. Bruce W. Hevly and John M. Findlay, 179–99 (Seattle: University of Washington Press, 1998).

the strenuous objections of many of his colleagues.[7]

Still others, however, refused what they saw as a Faustian bargain. Robert R. Wilson provides an illustrative example. Wilson had led the Research Division of the Manhattan Project. But the bombings of Hiroshima and Nagasaki disturbed him profoundly. "I remember being just… ill. Sick," he told the documentarian Jon Else in 1981, "to the point I thought I would … vomit. I was so overwhelmed when it happened, that that thing had happened. Still am." His reaction soured him on nuclear research: "At the end of the war then, I gave up my clearance, and have not worked on … nuclear energy in any of its aspect[s] … or on bombs."[8]

An influential segment of the physics community shared Wilson's distaste for applications that might be misused. High energy physicists, many of them Manhattan Project veterans, prided the intellectual purity of their field, and even boasted of its remoteness from human affairs. Upon being awarded a share of the 1976 Nobel Prize for the experimental discovery of the J/Ψ meson, Burton Richter bluntly informed a reporter who asked after his discovery's uses: "The significance is that we have learned something more about the structure of the universe. In terms of practical application right now, it's got none."[9]

Wilson himself generated the most iconic expression of this outlook during a 1969 congressional hearing on support for the National Accelerator Laboratory (NAL)—better known as Fermilab—of which Wilson would become the founding director.[10] When asked by Rhode Island Senator Joe Pastore whether the facility would contribute to national security, or competition with the Soviet Union, Wilson insisted that it would not. Instead, he continued, "it has to do with: Are we good painters, good sculptors, great poets? I mean all these things that we really venerate and honor in our country and are patriotic about. In that sense, this new knowledge has all to do with honor and country, but nothing to do directly with defending our country except to make it worth defending."[11]

Wilson's eloquent defence of physics as a form of culture has been widely quoted, but its context widely misunderstood. Wilson is often cast as nobly resisting in the face of pressure to serve defence needs or lose support. But Pastore, a supporter of the NAL, had different concerns in mind. As the Senator charged with selling the project to the appropriations committee, he wanted to be armed with a clear justification for the project. Vague promises that the facility would furnish "a better understanding of the subnuclear universe," but that, specifically, physicists "do not know what we will find," as the AEC Research Director Paul W. McDaniel suggested, seemed weak. Pastore lamented: "We have these Senators … going all over the country showing how many people are starving, how many people are hungry, how many people live in rat-ridden houses. Here we are asking for $250 million to build a machine that is an experimental machine, in fundamental high energy physics, and we cannot be told exactly what we are trying to find out through that machine."[12]

The NAL would get its funding, but Pastore's frustration reflected growing disquiet about the effects of large-scale science, especially in the context of other major government expenditures. In 1969, the United States was embroiled in a costly (in several senses) war in Vietnam. The Apollo program was in full swing, and would send astronauts to the moon in July, but would also consume almost $30 billion. In this context, with funding for the NAL

[7] Kai Bird and Michael J. Sherwin, *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer* (New York: Knopf, 2007).

[8] *The Day After Trinity*, directed by Jon Else (San Jose: KETH, 1981). Available at https://www.youtube.com/watch?v=Vm5f-CxXnK7Y. The quoted passages can be found at 1:03:08–1:03:29 and 1:07:58–1:08:11.

[9] "Yanks Sweep Science Field for This Year's Nobel Prizes," *Chicago Tribune*, October 19, 1976. For further discussion of this attitude, see: Joseph D. Martin, "Prestige Asymmetry in American Physics: Aspirations, Applications, and the Purloined Letter Effect," Science in Context 30, no. 4 (2017): 475–506; Hallam Stevens, "Fundamental Physics and its Justifications, 1945–1993," *Historical Studies in the Physical and Biological Sciences* 34, no. 1 (2003): 151–97.

[10] Lillian Hoddeson, Adrienne W. Kolb, and Catherine Westfall. *Fermilab: Physics, the Frontier, and Megascience* (Chicago: University of Chicago Press, 2008).

[11] *AEC Authorizing Legislation, Fiscal Year 1970: Hearings Before the Joint Committee on Atomic Energy*, 91st Cong. 86 (April 17 and 18, 1969), 113.

[12] *AEC Authorizing Legislation* (ref. 11), 111–12.

recently approved, solid state physicist Benjamin Lax complained that "millions are being spent on redundant facilities" while his own magnet laboratory the Massachusetts Institute of Technology languished.[13] The poet Gil Scott-Heron was equally sharp-penned in 1970, skewering spending on the moonshot in the face of poverty, inequality, and infrastructural decay, in his poem "Whitey on the Moon": "With all that money I made last year / For whitey on the moon / How come I ain't got no money here? / Hmm, whitey's on the moon."[14] Pastore, Lax, and Scott-Heron, though they represented different perspectives, shared a motivating question: what cultural priorities did big-science projects reflect? That same question motivated a second attack on the monuments of physics.

Critics of Monumental Physics

American high energy physics was in the monument business by the 1960s. Ernest O. Lawrence and M. Stanley Livingstone had invented the cyclotron in the early 1930s. This instrument for accelerating subatomic particles to high speeds allowed physicists to create interactions in the laboratory that revealed the workings of nature at its smallest scales. But the first cyclotron was small enough to fit in one hand. Later iterations grew larger as physicists grew hungry to accelerate particles, and smash them together, at higher velocities, which required bigger magnets.[15] By 1960, this process had led to machines like the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory on Long Island, 843 feet in diameter (figure 2).[16] Such monumental machines brought about a revolution in physical understanding of the sub-nuclear world, but they also stoked a revolution of a different type: a revolt against the values they encoded. In 1961, Alvin Weinberg published an article in *Science* entitled "Impact of Large-Scale Science on the United States," which critiqued the influence facilities like the AGS exerted on the American scientific community.[17] Weinberg was, in many ways, an unlikely revolutionary. As the director of Oak Ridge National Laboratory, a sprawling national research facility that had its roots in the Manhattan Project, he was an established member of the scientific–managerial class that guided American science during the Cold War. He was a physicist who had worked on the Manhattan Project, often regarded as the first true example of big science.[18] But he would credit the comprehensive, humanistic undergraduate education he received at the University of Chicago in the 1930s with conditioning him to understand science in terms of how it intertwined with human affairs.[19]

Weinberg examined the intertwining of big science with human affairs, and he didn't like what he saw. He compared the monuments of big science to monuments like the Pyramids and medieval cathedrals. Monuments might be spectacular, but "those cultures which have devoted too much of their talent to monuments which had nothing to do with the real issues of human well-being have usually fallen upon bad days."[20] Such bad days, he warned, might well be in store for the United States if it permitted questions of scientific merit to be arbitrated "in the congressional committee room rather than in the technical-society lecture hall," which would ensure that "the spectacular rather than the perceptive becomes the scientific standard."[21] Spectacle, in other words,

[13] Benjamin Lax, letter to Leland Haworth, May 10, 1967, NMLR, Francis Bitter National Magnet Laboratory. Records. MIT Archives and Special Collections, Cambridge, MA.
[14] Quoted in Andrew Russell and Lee Vinsel, "Whitey on Mars: Elon Musk and the Rise of Silicon Valley's Strange Trickle-Down Science," *Aeon*, February 1, 2017, https://aeon.co/essays/is-a-mission-to-mars-morally-defensible-given-todays-real-needs.
[15] For an overview of the theoretical development of particle physics, see Abraham Pais, *Inward Bound: Of Matter and Forces in the Physical World* (Oxford: Clarendon Press, 1988).
[16] For an account of early cyclotron development, see John L. Heilbron and Robert W. Seidel, *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory*, vol. 1 (Berkeley: University of California Press, 1989). On Brookhaven, see Robert P. Crease, *Making Physics: A Biography of Brookhaven National Laboratory, 1946–1972* (Chicago: University of Chicago Press, 1999).
[17] Alvin Weinberg, "Impact of Large-Scale Science on the United States," *Science* 134, no. 3472 (1961): 161–64
[18] Derek J. de Solla Price, *Little Science, Big Science* (New York: Oxford University Press, 1963).
[19] Alvin M. Weinberg, *The First Nuclear Era: The Life and Times of a Technological Fixer* (New York: American Institute of Physics, 1994), 3.
[20] Weinberg, "Impact of Large-Scale Science" (ref. 17), 164.
[21] Ibid., 161.

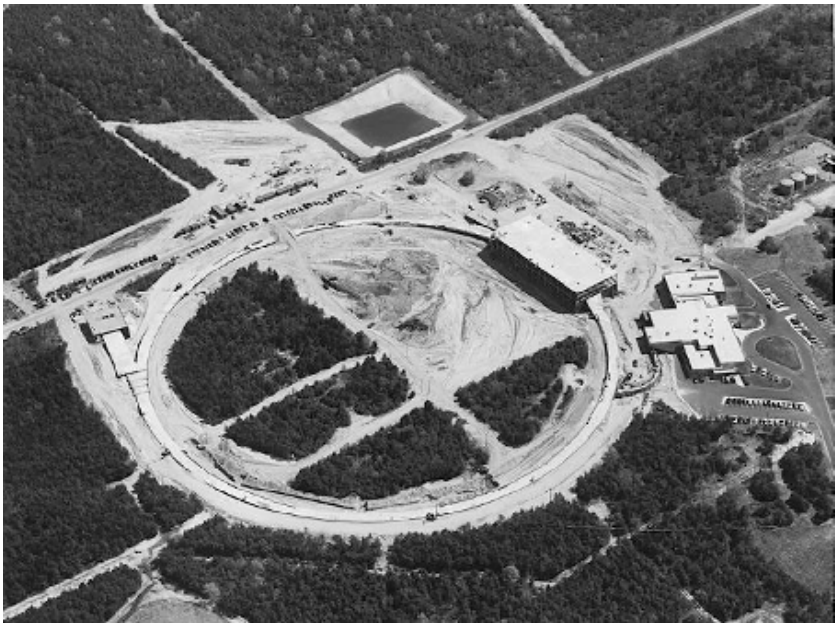

Figure 2. Aerial view of the AGS at Brookhaven National Laboratory during its construction.
Credit: Brookhaven National Laboratory, distributed under CC BY-NC-ND 2.0.

should not distort our sober evaluation of a scientific undertaking's worth in terms of benefits to society.[22]

This critique focused attention on the values that underwrote big physics. Critics who followed Weinberg's lead focused in particular on *reductionism*. This term has been used to name all manner of sin, but in the case of physics, it refers to the conviction that the whole natural world can in principle be described in terms of a single set of laws governing the workings of the universe at its smallest scales. Such a view was attractive to particle physicists in the twentieth century. Deciphering the workings of the elements of matter and energy held the promise of answering *the* most fundamental questions about the universe: an intellectual spectacle worthy of spectacular research facilities. And a reductionist approach led physicists of Wilson's stripe away from the uncomfortable prospect of generating applications they could not control.

But many physicists became worried, like Weinberg, when reductionism placed disproportionate value on the kind of science that was disproportionately distant from the terrestrial world. Philip W. Anderson, who conducted pioneering and fundamental work in solid state and condensed matter physics that clarified the mechanisms that underlie magnetism, among other phenomena, wrote a famous broadside against this form of reductionism, titled "More Is Different," in 1972.[23] Although we often learn about systems by breaking them down into their components, Anderson argued, we cannot then assume that knowledge of those components permits us to reconstruct or predict the properties of the higher-level systems they might constitute—to presume otherwise was simply "the arrogance of the particle physicist."[24]

Another condensed matter physicist, Leo Kadanoff, argued along similar lines. Like Anderson, he accepted that a reductionist approach, which often led to the unification of physical laws

[22] Weinberg expanded on this view in Alvin M. Weinberg, "Criteria for Scientific Choice," *Physics Today* 17, no. 3 (1964): 42–48. For further discussion, see Joseph D. Martin, *Solid State Insurrection: How the Science of Substance Made American Physics Matter* (Pittsburgh: University of Pittsburgh Press, 2018), ch. 7.
[23] Philip W. Anderson, "More Is Different: Broken Symmetry and the Nature of the Hierarchical Structure of Science," *Science* 177, no. 4047 (1972): 393–96. For further discussion, see: Joseph D. Martin, "Fundamental Disputations: The Philosophical Debates that Governed American Physics, 1939–1993," *Historical Studies in the Natural Sciences* 45, no. 5 (2015): 703–57.
[24] Anderson, "More Is Different" (ref. 23), 396.

once thought to be separate, had been a great driver of scientific progress. But, he qualified, "another part of the grand structure is the opposite view—that natural laws are diverse. Different laws may apply at different levels of organization."[25] Insufficient appreciation of this fact had led to the US science budget that was "increasingly misdirected toward grandiose projects" by the late 1980.[26]

The opposition to monumental physics that grew from the 1960s through the 1980s was multifaceted. It hinged on evaluating the connections among scientific fields, and between those fields and technical and social concerns, on philosophical commitments about the merits of different types of knowledge, and on internecine squabbles and personal politics. But at core, it was a question about priorities. By casting fundamental knowledge of the very small as valuable principally as a form of culture, high energy physicists distanced themselves from practical justifications for their work. They also left a question open for the asking: If physicists are like sculptors, artists, and poets, why are they funded so much better?

Even in the 1960s, as big physics was just beginning to establish its toehold on the research landscape, sceptics were asking that question. They were driven by an understanding that science is political. The choices we make as a society about what science to pursue and how to pursue it both speak to and reinforce our values. In that sense, supporters of high energy physics miscalculated if they hoped to distance themselves from political concerns by retreating to the distant world of quarks, bosons, and neutrinos.

Epilogue

In 1993, a monument fell. The Superconducting Super Collider (SSC) was to have been a massive particle accelerator, 54.1 miles in circumference. As a research facility it was, like the NAL before it, an effort to generate new data that would produce new, unpredictable insights into particle physics. As a monument, it was an effort to ossify the reductionist worldview, and the system of support it implied, by entrenching it in a colossal facility. By the early 1990s, the US Congress could not be convinced to support such an effort, and the monumental SSC, already in the process of being erected, was depleted.[27]

The SSC was unusual in facing vocal and determined opposition from within the physics community—even Weinberg, when castigating big science, restrained himself from actively opposing any specific project. The likes of Philip Anderson and Leo Kadanoff, however, were not content to follow the disciplinary tradition of keeping criticism of large-scale physics funding efforts to themselves. They were motivated not by an insatiable yen to tear the SSC from its pedestal, but by a conviction that something better could go in its place.

Monuments are meant to set certain ideals and practices in stone, and so tearing them down is a symbolic rejection of those ideals and practices, but also a meaningful attack on the material conditions that perpetuate them. Anderson, Kadanoff, Weinberg, and other critics of big science worried that the conditions that perpetuated big science were unhealthy for other areas of science. By opposing it, they sought to usher in a new age, once in which the basic pursuit of science and the practical employment of science worked together.

The critiques of big science that contributed to the demise of the SSC exhibit another important feature: they embraced, rather than rejected, the political entanglements of science. The idea of science as apolitical became a powerful one during the Cold War.[28] For high energy physicists, it soothed a wounded conscience and justified ongoing expenditures in support of increasingly remote research. But for practitioners of small science, whose work often exhibited closer connections to technology, the political consequences of scientific choice were easier to discern. The revolution they sought to enact by attacking monumental physics was a turn, with a look of recognition, toward the processes that determine what sort of science we value, and why.

[25] Leo P. Kadanoff, "Cathedrals and Other Edifices," *Physics Today* 39, no. 11 (1986): 7–9, on 7.

[26] Leo P. Kadanoff, "The Big, the Bad and the Beautiful," *Physics Today* 41, no. 2 (1988): 9–11, on 11.

[27] See Michael Riordan, Lillian Hoddeson, and Adrienne Kolb, *Tunnel Visions: The Rise and Fall of the Superconducting Super Collider* (Chicago: University of Chicago Press, 2015); Martin, *Solid State Insurrection* (ref. 22), ch. 9.

[28] Ironically, this notion was employed as part of deeply political American efforts to exert soft power abroad. See Audra Wolfe, *Freedom's Laboratory: The Cold War Struggle for the Soul of Science* (Baltimore: Johns Hopkins University Press, 2018).