NOTICE: This is the author's version of the work. It is posted here by permission of the AAAS for personal use, not for redistribution. The definitive version was published in Science 349, no. 6252 (4 September 2015), doi:10.1126/science.aac7351

Cult of the Machine

Ernest Lawrence and the soul of Big Science

by **Alex Wellerstein** (College of Arts and Letters, Stevens Institute of Technology, Hoboken, NJ 07030, USA; wellerstein@gmail.com)

Review of:
BIG SCIENCE
Ernest Lawrence and the Invention that
Launched the Military-Industrial Complex
Michael Hiltzik
Simon & Schuster, 2015. 549 pp.

High above the hills of the University of California, Berkeley, sits a physics laboratory that employs over three thousand people, boasts an association with thirteen Nobel Prizes, and has a budget of over $750 million dollars. The Lawrence Berkeley Laboratory, named after its founder, the famed American physicist Ernest Orlando Lawrence, is a national laboratory, reliant on government funding and, though it does exclusively unclassified research today, has a history tied directly to development of nuclear weapons. Once an oddity in the field of American science, the Berkeley lab is now just one of many that carry forward the mantle of "Big Science," and not nearly the largest such project, at that.

Lawrence's name adorns the Berkeley laboratory, its weapons-spinoff at Livermore, a US government award, and an element. By any standard he was a giant of American physics, and arguably the architect of a new style of science altogether: "Big Science," a term only coined after his death, but referred, often critically, to the late-20th century method of doing science that required big machines, big budgets, and big staffs.[1]

Michael Hiltzik, a Pulitzer-prize winning journalist for the *Los Angeles Times*, has made a foray into the history of physics with a new biography of Lawrence, the only such monograph published since Herbert Childs' (family-sanctioned) book *American Genius* came out in 1968.[2] As the title of the Childs book implies, someone like Lawrence can attract a hagiographical, uncritical treatment, as his brash "bigness" satisfies a particularly American vision of what success ought to look like, scientific or otherwise. As the reference to the military-industrial complex in the subtitle to Hiltzik's *Big Science*

[1] A. M. Weinberg, "Impact of Large-Scale Science on the United States," *Science* 134, no. 3473 (1961), 161-164; S. Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago: University of Chicago Press, 2008), 80-83.
[2] H. Childs, *American Genius: The Life of Ernest O. Lawrence* (New York: Dutton, 1968).

might imply, with time the criticisms of Big Science have grown, in particular its deep historical connections to military research.

What kind of scientist, and what kind of person, was Ernest Lawrence? An experimental physicist of a particular stripe, to be sure. Lawrence was less a discoverer than an inventor, more of a tool builder than a tool user. This is, of course, a legitimate strand of scientific development, though it is not always as immediately valued as the work of those who use said tools to probe the limits of nature. And at the center of Lawrence's world were these tools, these machines: circular particle accelerators, dubbed the "cyclotron." Around these initially humble creations, Lawrence build an empire of labor and of funding. And, eventually, in the hands of others, these tools did pave the way forward for a new kind of physics.

If we were to judge Lawrence only by his legacy in physics, it would already be a more complicated issue in the post-Cold War environment than it was during most of the 20th century. The old model of Big Science, where individual governments fork over huge sums of taxpayer funding to build monuments to discovery, with the vague expectation that military benefits might be produced as residual byproducts, appears to have ended, if not just stalled. Even by the 1960s there were increasing criticisms of the way these scientific mega-projects monopolized funding requirements, dissolved individual initiative, and frequently brought diminishing returns.[3]

But peering behind the curtain at Lawrence as a person, and Lawrence as a scientist, complicates the picture even further. Lawrence's style was not limited to just building new tools. It was also a labor model that relied on the "remorseless exploitation of cheap graduate-student labor," (50) as Hiltzik aptly puts it. Several of former students used the term "slave driver" (76) to describe his management style.

From his very beginning, Lawrence handed off the laborious part of building his machines to underlings, and immediately took credit for their work. His first cyclotron model, a mere six-inches in diameter, was constructed apparently entirely by a graduate student. Lawrence was singing its successes even before it was clear it worked — which, in fact, it didn't. (51) The first *functioning* model was developed by his next student laborer, Stanley Livingston, who debugged the earlier machine and fixed its numerous errors. Even before Livingston had really put the cyclotron prototype through its paces, Lawrence was hot on the trail for the money needed to build a bigger model. (54) Such was a hallmark of the Lawrence approach: build one machine to get the attention, and money, for the next machine, and start the next project before the first one has actually borne fruit.

Lawrence's approach was viewed with justifiable skepticism among the scientific greats of Europe. For its first decade, it failed to produce real results. Lawrence claimed bigger and bigger energies, but did little with them. His first major scientific announcement, a

[3] P. Galison and B. Hevly, eds., *Big Science: The Growth of Large-Scale Research* (Stanford: Stanford University Press, 1992).

theory of deuteron disintegration, proved to be a terrible, embarrassing, time-wasting flop. Instead of proving a new physical phenomenon that overturned the laws of physics as known, Lawrence instead broadcast on a world stage the Radiation Laboratory's inability to keep its samples clean. (118)

Lawrence's problem, as diagnosed by his contemporaries, was that he was more interested in the "cult of the machine" (119) than the scientific results, and the number of major discoveries of the 1930s that the Rad Lab ought to have stumbled across, had they been watching for them, is a long one. A French visitor ridiculed the laboratory for having "a mania for gadgets or a post-infantile fascination for scientific meccano [sic] games" (160), while many former employees would caution against the "slipshod" method of working (126). Lawrence prided cheap, furious labor above all else, creating an environment not only not conducive to the hard, careful work of serious scientific insight, but also a work environment rife with electrical and radiation hazards.

Yet, someone paid for the machines. Why? In part because of what Lawrence would at one point dub "the vaudeville" (136), his ability to project boundless enthusiasm and confidence to non-scientific audiences. Donors fell under his sway, even if other physicists were dubious. As a result, he got his machines — ever bigger, even if, as he once admitted in a rare piece of candor, he was making them bigger simply because he could get the money to do so, not because he had any idea about what the bigness would let him do. (174)

But to a large degree, it worked. The cyclotron went from being a crazy venture to a common tool, getting Lawrence his coveted Nobel Prize. Why? Part of this is because, in the right hands, they did yield important results. Ed McMillan, Luis Alvarez, and Glenn Seaborg all cut their teeth, and did some of their best work, working at the Radiation Laboratory, finding ways to make Lawrence's chaotic fiefdom work for them. Additionally, when it became clear that cyclotrons could produce radioisotopes in quantity for other types of scientific research, the demand for them rose across the world, and Lawrence was happy to assist in the exporting of his tools, knowing that he could only gain from their rising applicability.

The Second World War brought what would become Lawrence's ultimate patron, whose expenditures made his earlier acquisitions look paltry in comparison. The US military establishment arrived at Lawrence's door, first for radar and then the atomic bomb, and never really left. Lawrence's was one of the loudest proponents for building the atomic bomb, largely because he claimed that he could practically pull it off single-handedly. He could not, and he arguably met his match in a results-driven General Leslie Groves, who did not accept the kinds of delays, half-excuses, and cost-overruns that Lawrence had become accustomed to getting away with. (274)

While other scientists went soul-searching after the bombings of Hiroshima and Nagasaki, Lawrence never demobilized. He comes off as particularly shallow and unreflective in the immediate postwar period. He complained that the scientists who participated in the discussions about the domestic control of atomic energy, and believed they had a special responsibility to the present moment, were “frittering away so much time and energy on political problems, when they could be devoting themselves to scientific pursuits.” (315) In response to his former colleague J. Robert Oppenheimer’s expressions of doubt, Lawrence glibly remarked that, “I am a physicist and I have no knowledge to lose in which physics has caused me to know sin.” (300) If one believed these sentiments were rooted in true conviction, rather than a self-interested desire for a new means to even bigger science, one might be inclined to give Lawrence the benefit of the doubt. But it is all too easy to read these cynically, as Lawrence benefitted immensely from taking such unruffled positions about the militarization of science.

Some of these positions caught up with him. His unwavering support for anti-Communist loyalty oaths and internal investigations led to an exodus of top-flight theoretical physicists from his laboratory. (335) He was at least as important a pusher of the thermonuclear “Super” bomb in 1949 as Edward Teller, and later lent his name, and credibility, to the many of Lewis Strauss’ more questionable Cold War projects, like the so-called “clean bomb” as an excuse to maintain nuclear testing. Lawrence was a key player in the Oppenheimer affair, testifying secretly against his former friend, turning the Rad Lab into a hub of anti-Oppenheimer activity. (378) Only at the last minute, fearing retribution and claiming illness, Lawrence begged out of testifying at the Oppenheimer security hearing itself. (382) Teller, for all his flaws, at least owned up to his opinions publicly, while Lawrence preferred to stay in the shadows.

Lawrence secured his funding, and his laboratory’s future, in the Cold War, but it came with falters. Trying to set up the Livermore laboratory along a Rad Lab model (cheap workers surrounding an all-powerful director) produced a string of nuclear fizzles. (370) His funding requirements became harder to procure when the people judging his project proposals were fellow physicists, less susceptible to his infectious optimism. (359) His brief foray into private industry, in developing the Chromatron color television tube, ended in a lackluster failure, because the very things Lawrence was good at (over-budgeted one-off technical accomplishments) were precisely the opposite of the requirements for successful consumer electronics. (394) All the endless work and stress took a heavy toll — Lawrence’s death appears directly linked to his endless, unceasing ambition. (426)

Hiltzik’s book seems uncertain what genre it wants to be: blushingly flattering at times, damningly critical at others, it never quite gets inside Lawrence’s head. What was it that drove the man? A true devotion to science, or to ego? Is he a scientific hero, or a cautionary tale of a Faustian figure who loses his soul to the cult of the machine? Hiltzik never really engages the question, much less answers it, but it is hard to not feel this conflict on nearly every page. It is the conflict, ultimately, of the amazing transformation of science over the course of the 20th century, and as Lawrence was at the center of that transformation, so the conflict is at the center of him.