Science and Technology in the Global Cold War

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1 Science in the Origins of the Cold War

Naomi Oreskes

In *Military and Political Consequences of Atomic Energy*, first published in the United Kingdom in 1948 (and in the United States a year later under the catchier title *Fear, War and the Bomb*), the physicist P. M. S. Blackett declared that the dropping of the atomic bombs on Japan was "not so much the last military act of the Second World War as the first major operation of the cold diplomatic war with Russia now in progress."[1] Blackett was one of many, then and now, who have tried to assess the role of the atomic bomb—and therefore, implicitly, of science—in ending World War II and launching the Cold War, as well as the significance of the Cold War in altering the course of science.[2]

At the end of World War II, many scientists emphasized the bomb's significance—perhaps because the greater the bomb's role, the greater their role. If the bomb were crucial either in ending World War II or in beginning the Cold War, then science and scientists were crucial too, and perhaps had a further role to play in helping to control it. Niels Bohr argued that the unprecedented power of nuclear weapons necessitated new forms of international governance.[3] George Orwell agreed that nuclear weaponry heralded the dawn of a new age—and not a good one. In the essay in which he coined the term "Cold War," Orwell argued that the atomic bomb was so terrifying that it would put an end to conventional warfare, but that, counterintuitively, this was *not* good, because the bomb would put in its stead a hideous peace as "horribly stable as the slave empires of antiquity." The world would find itself in a permanent state of "cold war," and the West would be unable to act decisively when conditions called for it.[4] Blackett (and others) didn't believe that the atomic bomb would make other forms of weaponry obsolete, much less end conventional warfare; they noted dryly that US generals had shown no sign of giving up their conventional forces. The atomic bomb, Blackett suggested, was in some sense an extension of the World War II policy of massive bombardment of civilians, and just as unethical. After all, how was destroying a Japanese city with one bomb much different from destroying a German city with many bombs (an argument that the bomb's defenders would later use, although to opposite effect than Blackett intended)?[5] Blackett noted that a "huge weight of ordinary bombs" had been dropped on Germany "without leading to a decisive failure of either production or civilian morale," suggesting that, as awesome and frightening as atomic weaponry was, it had not been decisive in World War II and it wasn't likely to prove decisive in future wars either:

> Three million tons of ordinary bombs were dropped by British and American aircraft in the European and Pacific Wars. Since one atomic bomb of the 1945 type produces ... about the same material destruction as 2,000 tons of ordinary bombs, it is certain that a very large number of atomic bombs would be needed to defeat a great nation by bombing alone.[6]

Nuclear weapons were powerful, to be sure, but it was a mistake to overestimate their significance, because that might lead to hysteria, which in turn would make it harder to negotiate with the Soviet Union to find a route to a lasting, stable peace. (It would also make it more difficult to develop civilian nuclear power generation.[7]) Overestimation of the bomb's power was leading to "a hysterical search for 100 per cent security," a security that could never be achieved.[8] It was generating pressure for a huge buildup of weaponry. (Blackett cited the logic of the "Irishman" who "on seeing a stove advertised to save half one's fuel, he bought two to save it all!"[9]) Worst of all, hysteria about the power of the bomb in the hands of enemies led to the hideous suggestion that a pre-emptive strike might be justified—a suggestion that would indeed be made at various points during the Cold War and afterward.[10]

In hindsight we can see that both Blackett and Orwell were partly right. The world did plunge into a Cold War—a deep freeze of animosity between the United States and the Soviet Union that chilled much of the rest of the world as well—and Orwell's term took hold to describe it.[11] The Cold War had a range of negative consequences, though perhaps not as dark or as monolithically negative as Orwell feared.[12] And science was central to the Cold War, because it had been scientists who had perceived the possibility of nuclear weapons, scientists who had built them, and scientists who continued to develop the means of testing, hiding, detecting, and delivering them.[13] Blackett, for his part, was correct that the Cold War climate included a significant component of hysteria, leading both sides to demonize the other, and to insist on the necessity of stockpiling tens of thousands weapons that neither side ever used or wanted to use. Nor did these expenditures prevent either side from spending comparable resources on conventional weapons. On neither side were generals prepared to give up their conventional forces—even after the development of the hydrogen bomb, which was thousands of times as powerful as the bombs dropped on Hiroshima and Nagasaki. The premise that nuclear weaponry would be more economical than conventional forces also proved false, as both sides built both massive nuclear forces—tens of thousands of nuclear weapons, thousands of bombers, hundreds of ICBMs (and still more intermediate-range ballistic missiles), and scores of nuclear submarines—and massive conventional forces of troops, tanks, battleships, and aircraft carriers.[14] As

President Dwight Eisenhower put it in his farewell address, both sides were compelled to "create a permanent armaments industry of vast proportions."[15] This industry cast a long shadow, as citizens of not only the United States and the Soviet Union but the rest of the world as well lived under the threat of Mutual Assured Destruction. Indeed, at the start of his presidency, Eisenhower went further, describing life during the Cold War as "not a way of life at all in any true sense." "Under the cloud of threatening war," he continued, "it is humanity hanging from a cross of iron."[16]

In 1997, the historian Walter LaFeber looked back and summarized the American Cold War experience this way: "It has cost Americans $8 trillion in defense expenditures, taken the lives of nearly 100,000 of their young men and women, ruined the careers of many others during the McCarthyite witch hunts, [and] led the nation into the horrors of Southeast Asian conflicts. … It has not been the most satisfying chapter in American diplomatic history."[17] No doubt one could say something similar from the Soviet perspective. There were costs to other nations as well, as they felt compelled to establish their own nuclear weapons programs, participated (both knowingly and inadvertently) in the nuclear tests of other nations, or became sites of nuclear weapons facilities and thus potential targets in a war.[18]

What did science have to do with all this? The atomic bomb could not, of course, have been built without scientific insight and technical prowess—the discovery of nuclear fission, the detailed determinations of the requirements for critical mass, and the extensive work on materials, electronics, and conventional explosives that made the atomic bomb possible, and so scientists and historians of science have placed great emphasis on the role of the atomic bomb in creating the Cold War world.[19] The bomb, it seemed obvious at the time, at least to the scientists who had helped to build it, had transformed the world. As Martin Sherwin argued in a book that has gone through multiple editions and has been repeatedly described as "definitive," the bomb destroyed the old world—a world where war was generally fought between near neighbors—and replaced it with a new world of global conflict.[20] In the old world, wars were fought by uniformed soldiers, primarily on battlefields; in the new world, warfare would spread everywhere—on the land, in space, and beneath the sea. Civilians in cities would be the primary targets: the threat of megaton nuclear weapons meant that no one was safe. As Nevil Shute made indelibly clear in his novel *On The Beach*, even those who survived nuclear blasts in remote locations would be victims of fallout. And scientists, it seemed, were largely to blame, for they had started the whole thing.[21] But had they really? As Michael Gordin has noted, the Cold War was as much about *knowledge about knowledge*—who had it and who didn't—as it was about the knowledge itself.[22] And as Odd Arne Westad has emphasized, the global Cold War was as much about politics and ideology as it was about advanced weapons and their delivery systems.[23] While historians of science and technology have emphasized the role of scientific and technical knowledge—the role of the bomb in triggering the Cold War and the arms race in sustaining it—political historians have tended to see the matter somewhat differently.

The Political Origins of the Cold War

In his classic work *The United States and the Origins of the Cold War, 1941–1947*, John Lewis Gaddis found the political origins of the Cold War not so much in the use of the bomb at the end of the war as in irreconcilable differences between two opposed political and economic systems.[24] His periodization immediately tells us that the bomb is, at most, one piece of a larger story.

The driving force behind President Franklin Roosevelt's approach to World War II, Gaddis argues, was a desire to end it correctly by paying attention to the political and economic dimensions of a lasting peace. One lesson of World War I was that the nations that had started the war should be defeated and disarmed completely. Ambiguity had permitted German leaders to tell their people that they had not really been defeated in World War I but had been betrayed by their leadership, and that victory in a second round of fighting was plausible. A second lesson was that it was necessary to avoid the political and economic conditions that had led to totalitarianism in Germany, which in turn entailed a need for self-determination among the peoples of defeated nations, an imperative to prevent future economic depressions, and a need for some form of international governance. "American failure to join the League of Nations," Gaddis wrote, "had also contributed to the collapse of international order; therefore a third prerequisite for peace would be membership in a new collective security organization."[25] To achieve these goals, it would be necessary to maintain decent relations among the United States, the United Kingdom, and the Soviet Union once World War II was over.

According to Gaddis, "Roosevelt and his advisers clearly realized that their vision of the future would not materialize unless the members of the Grand Alliance, united now only by their common enemies, built relationships that could survive victory."[26] One might argue that the bomb poisoned the possibilities for enduring friendly relations, but one might equally argue that President Harry Truman used the bomb because he and his advisors had concluded that such prospects had already vanished.[27]

Ghosts of Depression Past and Future

Walter LaFeber defined the Cold War period as 1945–1996, but, like Gaddis, he looked back from 1945 to find its origins. The World War II alliance of the United States and the Soviet Union was a "shotgun marriage" preceded by a long history of conflict and animosity, much of it centered on trade. Late in the nineteenth century, LaFeber noted, Russia and the United States had "confronted each other on the plains of North China and Manchuria."[28] As the American economy expanded dramatically, Americans looked to Asia "as the great potential market for their magnificently productive farms and factories." Russians, however, after "annexing land in Asia," "tried to control it tightly by closing markets to foreign business people with whom they could not compete."[29] This control of competition, along with a distaste for Czarist repression sustained by horror stories carried to the United States by immigrants, had produced deep animosity in the United States toward Russia well before the 1917 revolution or the 1924 rise to power of Joseph Stalin. Russians, for their part, were not pleased by President Woodrow Wilson's refusal to open diplomatic relations after World War I, by his sending US troops in an attempt to overthrow Lenin, or by the creation in 1919 of the buffer states of Poland, Romania, Czechoslovakia, and Yugoslavia.[30]

The belief that the prosperity of the United States required an "open door" to Asia was reinforced by the Great Depression. As World War II came to a close, political leaders were mindful that the global economy had been had been pulled out of depression at least as much by the war as by the New Deal, and the urgency of international trade as a means to avoid a slide back into depression weighed heavily on allied minds. LaFeber saw trade as the central point of contention between the United States and the Soviet Union as World War II drew close. The US and its European allies, haunted by what LaFeber called "the Ghosts of Depression Past and Depression Future," were determined to keep global markets open. Secretary of State Dean Acheson put it this way: "We cannot expect domestic prosperity under our system without a constantly expanding trade with other nations."[31] Western leaders feared that without open markets the West would not only slide back into depression but would also slide into totalitarianism. Vice President Henry Wallace put it this way: "In the event of long continued unemployment, the only question will be as to whether the Prussian or Marxian doctrine will take us over first."

The idea that capitalism needed to expand indefinitely in search of markets was a central belief of Trotskyites and a major reason for the Soviet fear of "capitalist encirclement." Moreover, the specter of capitalist expansion ran headlong into the Soviet desideratum of a buffer zone of friendly socialist states in Eastern Europe. Russia had a long history of invasion by unfriendly neighbors, and had suffered devastating losses in World War II: more than 20 million fatalities, and more than 25 million left homeless.[32] Ideological clashes with the West aside, it was no surprise that the Russians were deeply concerned to end the war with safe and secure borders. LaFeber thus agrees with Gaddis that conflict was inevitable: "Roosevelt faced a choice: he could either fight for an open postwar world (at least to the Russian border) or agree with his ally's demands in Eastern Europe."[33] If he chose the first, Russian-American relations would collapse; if he chose the second, the world economy might collapse.

Roosevelt died before he had to make that choice, but his successor, Truman, decisively chose the first option. The atomic bomb figured heavily in his calculations, as Truman believed it had strengthened his hand and might enable him to wrest concessions from the Soviets. We know now that he misjudged. Stalin wasn't impressed by Truman's suggestion at Potsdam that the United States was in the possession of a uniquely destructive weapon; thanks to spying, he already knew it.[34] Short of actually using the bomb against the Soviets, it wasn't clear what advantage the bomb gave the United States, and Truman and his advisers "never figured out how to use the bomb to obtain concessions they wanted from the Soviets."[35] Meanwhile, the Soviets accelerated their own work on nuclear weapons. Whatever effect the bomb did or didn't have on the conclusion of World War II, its use clearly marked the beginning of what would become a long and costly arms race. It also dramatically altered relations between science and the modern nation-state—between nation and knowledge—in both the United States and the Soviet Union. And it changed what it meant to be a scientist in the new, security-driven nation-state.[36]

Nation and Knowledge

As the Cold War deepened, science and scientists were enlisted to support it in a variety of ways.[37] It is well documented that the Cold War provided the justification for massive increases in the US government's support, through existing and newly created federal agencies and through direct grants to researchers at colleges and universities across the country, for both basic and applied scientific research—some of it to be done at the newly established national laboratories.[38]

National security provided the justification for this huge increase in federal support for scientific research. The Office of Naval Research, created in 1946 from diverse wartime programs, explicitly authorized the Navy to plan, foster, and encourage "scientific research in recognition of its paramount importance [in] the preservation of national security." When the National Science Foundation was created four years later, in part on the ONR model of funding investigator-initiated projects, it was charged with fostering science to "to advance the national health, prosperity and welfare," but also " to secure the national defense." Science was also funded by new federal agencies, including the Atomic Energy Commission, the Advanced Research Projects Agency, and the expanded National Institutes of Health, whose extended research mandate included radiation sickness and nuclear medicine.[39]

All this makes it abundantly clear, that, whatever the role of science in the Cold War, the Cold War drove substantial changes in the scale and funding structure of American science. Yet, if the issue of the effect of science on the Cold War has long been argued, the reverse question (How did the Cold War affect science?) did not receive sustained academic scrutiny until relatively recently.

The Cold War's Effect on Science: Moving Past Miasma

Historians have long been interested in how cultural and political context affects the growth, development, and content of science. However, much of our work has suffered from what one might call a "miasma problem": it is easy to describe the culture surrounding a given science, much harder to demonstrate its causal effects. (No doubt there *were* miasmas in the nineteenth century, but that didn't prove that they caused the diseases that occurred in their midst.) One reason for this is the innate complexity of human experience: we rightly shy away from simplistic determinative accounts of complex historical developments. We recognize that the course of human events is long and winding. At the same time, we emphasize the necessity of placing the production of scientific knowledge in its full social, cultural, political, and even economic context, tending to be critical—sometimes harshly so—of histories that fail to do so. Our sociological colleagues go further, insisting that scientific knowledge and society are co-produced.[40] But if context is important, and certainly if knowledge is co-produced, then it behooves us not to simply use context as a kind of "background"—like the lakes and trees in Renaissance portraits—or even as a frame that highlights only some aspects of our picture, but rather to attempt to explain the *particular* ways it was important in any given situation. Put another way, what is the point of placing knowledge into its full historical context if that context doesn't help to explain how and why particular lines of inquiry were pursued, and other lines of inquiry were abandoned or left unpursued?[41] Our quarry is the development of scientific (and technical) knowledge, but is it even *possible* to demonstrate that a particular cultural setting played a determinative role in the content of knowledge produced in that setting?

At least one historian has tried. In 1971, Paul Forman put forward the controversial suggestion that the development of quantum mechanics—and specifically the assertion of acausality in quantum mechanics—was a direct result of the devastating defeat of Germany in World War I. In anger, frustration, and confusion about the inexplicable outcome, German intellectuals turned against determinism, rationality, and causality. Scientists, as intellectuals, weren't immune from this reaction, Forman argued, and they too began to doubt conventional rationality and to consider others forms of explanation. The Forman thesis—as it came to be known—was that this state of affairs led scientists "ardently to hope for, actively search for, and willingly embrace an acausal quantum mechanics."[42] Although there were, to be sure, peculiar quantum physical phenomena that required explanation, and which *could* be explained acausally (he wasn't suggesting that quantum mechanics was untrue), Forman proposed that scientists began to seek out accounts that were compatible with their cultural milieu, and they found it in acausality:

> In the years after the end of the first world war, but before the development of an acausal quantum mechanics, under the influence of "currents of thought," large numbers of German

physicists, for reasons only incidentally related to developments in their own discipline, distanced themselves from, or explicitly repudiated, causality in physics.[43]

As cultural conditions made the world seem increasingly inexplicable, physical phenomena were increasing viewed as inexplicable too. And as conventional notions of cause and effect lost their persuasive power in politics, they also began to lose their persuasive power in other domains—even in a domain that a previous generation of historians might have thought was immune to such considerations (and that many if not most scientists still think is impervious.) Previously, an explanation in physics was, by *definition*, causal; now, at least in the domain of quantum mechanics, it was acausal.

It was a striking reversal, and not all scientists found it congenial (Albert Einstein didn't), but Forman argues that many scientists embraced quantum mechanics not only happily but with a sense of *relief*. Speaking of the new theories in quantum mechanics, the mathematician Hermann Weyl, one of the founders of gauge theory and one of the first to apply group theory to quantum mechanics, wrote of the freedom to be found in quantum mechanics:

> [T]he rigid pressure of natural causality relaxes, and there remains, without prejudice to the validity of the natural laws, room for autonomous decisions, causally absolutely independent of one another. ... The "decisions" are what is *actually real* in the world.[44]

Acausality was a startling break from historic tradition in physics, whose purpose, some might argue, was to give causal accounts of natural phenomena. Forman's argument that such a striking change—such an *abandonment* of historic goals and aspiration—requires explanation is not in that sense particularly radical: historians of science routinely accept that changes in intellectual commitments require accounts. What was radical at the time was that Forman found that account not in the improved appraisal of the phenomena of nature but in the cultural adaptation "of knowledge to the intellectual environment."[45]

The Forman thesis, which seemed to suggest that German scientists had capitulated to irrationality, offended most physicists and many historians. Yet it was and remains highly influential—a Google search of "Forman thesis" turns up 402,000 hits. It raised the question of why we bother to pay attention to the cultural context of science unless we believe that context has affected the content of science in a significant way.[46] Returning to our particular topic, we might therefore ask: Is it possible to distinguish what happened to science during the Cold War from what happened to it because of the Cold War?

In 1987, Forman took up the challenge again, this time addressing Cold War physics. His quarry was not so much any specific physical theory as the nature and character of physics as a discipline. Forman now suggested that US military funding had dramatically altered the nature of physics, causing its practitioners to shift from seeking a fundamental understanding of the laws of nature toward gadgeteering preoccupied with technical prowess.[47] Forman's starting point was something that scientists themselves had said and many historians had accepted as self-evident: "World War II was in many ways a watershed for American science and scientists. It changed the nature of what it means to do science and radically altered the relationship between science and government ... the military ... and industry."[48]

While scientists and historians accepted that World War II was a watershed, restructuring the relationship between science and government, they largely interpreted that change in quantitative and normative but not epistemic terms. It was obvious that the federal support for science had increased dramatically, and it was generally assumed that this was a good thing. Scientists needed money for science, so most scientists found it hard to see more money as problematic.[49] Historians of science in the 1960s and the 1970s generally admired and approved of science, so they tended to accept that appraisal. Left largely unanswered—indeed, largely unasked—was the question of how government patronage affected the content of scientific research and the character of the knowledge produced. For although it was widely supposed that the federal government was increasing its support for scientific research because of its value for national security, it was frequently (and paradoxically) asserted that federal support allowed scientists to pursue whatever their curiosity dictated.[50]

This paradox was scarcely noticed, much less examined. But if the federal government supported science *because of* its value for national security, wouldn't it stand to reason that it would privilege particular sciences (physics, electronics, computer science) that were obviously pertinent. Wouldn't it tend to neglect less pertinent sciences (ichthyology, botany)? And wouldn't it make sense that within individual sciences, such as physics, government patrons would tend to want to focus financial, logistical, and moral support into lines of inquiry deemed likely to produce valuable results? ("If oratorios could kill," the biochemist Erwin Chargaff quipped in 1978, "the Pentagon would long ago have supported musical research."[51]) Indeed, wouldn't it be a dereliction of duty if these agencies supported science without regard to national needs and priorities?[52]

Forman cited statistics on physics research in the United States at the height of the Cold War. From the end of World War II through the late 1950s, about 95–98 percent of the federal support for physics research came from either the Department of Defense or the Atomic Energy Commission. "The only significant support for academic physical research in the US were the Department of Defense and an Atomic Energy Commission whose mission was de facto predominantly military,"[53] Forman asserted. The growth of the National Science Foundation in the late 1950s and the 1960s changed the situation only modestly: the component of research support from the DOD and AEC dropped to around 90 percent.[54] "Thus, in the fifteen years following the war," Forman concluded, "the central fact of scientific life in physics was unprecedented growth based upon military funding."[55]

"What direction of the advance of science, and thus what kinds of science, result from military sponsorship?," Forman asked.[56] If he who pays the piper doesn't call the tune, then what is he paying for? If it was "a bit too crass" to assume the golden rule (that those with the gold rule), it was equally implausible that this huge transformation in the quantity and source of support for physics didn't alter the nature and the character of the physics done.

What kind of science *did* result? For Forman, the short answer was solid-state physics and quantum electronics, which expanded even more rapidly and more extensively than other areas of physics. Forman also suggested several mechanisms by which work in solid-state physics and quantum electronics was fostered. Most obviously, program managers in the Office of Naval Research, the Air Force Office of Scientific Research, and other agencies made choices about what projects would be funded and what projects would not. Less obviously, they encouraged and stimulated scientists to consider working in areas of military interest, in part through site visits to colleges and universities, in part by organizing workshops and conferences on particular themes, and in part through ongoing informal discussions. Scientists supported by those agencies were bound to consider what kinds of work and results would be likely to get continued support. "Whatever such program officers did beyond providing funds," Forman wrote, "must be reckoned as direction of research. The funding levels of their programs and the contentment of their table of researchers depended upon reconciliation of the interests of their military and their scientific constituencies, a reconciliation effected chiefly by envisaging and promoting military applications in and through basic scientific research. For the researcher himself, 'the mere need to defend what he is doing to a particular sponsor may be the factor which will trigger an important application.'"[57]

A scientist who valued the funding that he or she (although during the Cold War mostly he) was receiving would be sensitive to nuances of interest and applicability. Beyond the defensive motivation of accountability to patrons and the desire to be invited back to the table, there was also the positive motivation of the gratification that comes with knowing that one's work is valued and perhaps put to use.[58] Paul Edwards has used the term "mutual orientation" to describe the interactions and feedbacks by which scientists and military patrons found common ground. Describing Jay Forrester's work in Project Whirlwind, Edwards concludes that "the source of funding, the political climate, and their personal experiences oriented Forrester's group toward military applications, while the group's research eventually oriented the military toward new concepts of command and control."[59] Part of the job of the agencies was to stimulate scientists to work in areas of basic research that might prove useful to the military, if not immediately then perhaps in the long run; part of the work of scientific researchers was to find ways to connect their abilities to the needs and interests of their patrons. Harvey Brooks referred to this as "imaginative stimulation"; I have called it a "context of motivation."[60]

If work proved irrelevant to an agency's mission, program officers had the option of cutting it off, but the available evidence suggests that they seldom felt a need to do so. Some would take this as proof that the scientists *were* free to do what they wanted, but a more plausible explanation is that intelligent scientists would have been unlikely to propose lines of inquiry that were doomed to be rejected, and there were enough interactions between scientists and funders that any idea that didn't resonate would be unlikely to be developed sufficiently to reach the stage of overt rejection.[61]

For Forman, the net result was a science that was "effectively rotated ... towards techniques and applications." The construction of masers and atomic clocks and the improvement of microwave technologies and electronics constituted advances, to be sure, but in tools more than in conceptual understanding—one might even say in technology rather than in science, although Forman himself resists that characterization. The physics of the Cold War was an "instrumentalist physics of virtuoso manipulations and *tours de force* ... just such a physics as the military funding agencies would have wished."[62] This, then, is why Forman concluded that physicists "had lost control of their discipline." It was because the physics that physicists ended up with—the physics that they now found themselves doing—was focused *in areas that had not previously been viewed as priorities by physicists, but were priorities for their military patrons.*[63] Something had changed the priorities of physics and physicists, and that something, Forman argued, was the Cold War.

Again Forman's views proved controversial; the historian Dan Kevles, in particular, contested his claims.[64] Kevles agreed with Forman that physics had proved decisive in World War II; that American technological superiority in that war had been achieved primarily by civilian scientists working under the auspices of the federal government through the Office of Scientific Research and Development; that after the war there was broad agreement among leading scientists, politicians, and military officers that it would be important to maintain and foster the scientific-military alliance that had proved so valuable to the Allied victory; and that all this provided justification for a massive expansion of American physics and increase in federal financial support for physical science research. Above all, he agreed that there had been a "transformation of the relationship between science, especially civilian science, and the American state after World War II."[65]

What was at issue was the character of that transformation. Kevles strongly contested the suggestion that the federal government hadn't supported basic research. Indeed, he took it as a lesson learned during World War II that abstruse knowledge in pure science could prove important in unexpected ways, and that this provided a substantial part of the federal government's motivation to sustain basic science in the years to come. Kevles also took it as accepted by the historical actors that science and technological development were not either/or propositions, and that agencies and military patrons understood that advances in technology required advances in the underlying science that supported them. "Postwar national security required energetic federal programs of both pure and defense-related research," Kevles argued, suggesting that both were energetically supported. Finally, it was clear, although Kevles made this point only in passing, that the demand for large numbers of trained scientists and engineers was a major driving force for support of universities, where basic science continued to flourish.[66] "The government sponsored major programs of research in practical areas such as nuclear weapons and impractical ones such as high energy physics," and the net result was "a vital and balanced scientific enterprise."[67]

Although Kevles found large areas of agreement with Forman, he contested the claim that physicists had lost control of their intellectual agenda, had been "seduced" by the largesse of federal funding, or had fallen prey to the "self-delusion that they were engaged in basic research of intrinsic interest while in reality they were merely doing the military's bidding." The United States had always been a "practically oriented culture," Kevles noted, in which "the technological sciences had always tended to command more attention than the pure sciences," so it was hardly surprising that this remained the case as physics expanded under governmental largesse.[68] (Kevles didn't say, but it logically followed from his argument, that if physics changed between 1930 and the 1960s, one reason may have been that it changed from being dominantly a European activity to dominantly a North American one.)

Kevles emphasized that scientists served on many leading advisory boards and committees, including the crucial Science Advisory Committee created by President Truman and greatly strengthened by President Eisenhower. Some of them, by virtue of their positions on these boards and committees, were close to power and involved in decisions about the future and the direction of American science. Most of them were committed to the alliance of science and technology with the mission of national security and proactively advanced that agenda; they weren't pawns of the admirals and generals. The same was true of many rank-and-file scientists:

> [F]or many of those physicists, national security was not a mere distraction. It was the life blood of their profession. ... One is hard pressed to imagine the great accelerator laboratories in the United States having come to exist and to flourish in the absence of the deep concern for national security that came to pervade the United States after World War II. Also, many physicists found abundant opportunities to do interesting physics by involving themselves in militarily-supported research of technological pertinence.[69]

In any case, Kevles concluded, it is counterfactual to argue on the basis of what scientists might have done in a different world. There is no essential definition of what constitutes physics. "Physics is what physicists do—or have done," Kevles concluded, not illogically but perhaps tautologically.

With the benefit of distance, it seems clear that Forman and Kevles *agreed* that the orientation of American physics during the Cold War became aligned with the national-security agenda. The agreed that during the Cold War knowledge was linked to the geopolitical ambitions of the American nation-state to an extent and a degree that it had not been before. Kevles allowed that physics was "restructured, its efforts diversified into intellectually promising areas made hot by the needs of national security."[70] Forman held that there was a "radical change in attitude toward science, toward national security, and toward the relationship between them on the part of both the military and the civilian leadership of the United States."[71] These claims seem entirely compatible.

Where Forman and Kevles disagreed was in the normative domain: They diverged on whether physicists were responsible for that alignment or victims of it, whether that alignment was a good thing, and whether scientists' self-image and self-appraisal was realistic or wishful. Kevles affirmatively characterized the re-organization of physics during the Cold War as a diversification that produced a "vital and balanced" scientific enterprise, which scientists themselves were largely responsible for directing. Forman concluded, less happily, that the ship was bigger, but narrower and tilted, and physicists were no longer steering it. Kevles saw the integration of physics into a national-security system as providing expanded opportunities for physicists to do physics; Forman agreed that physics was integrated, but saw that integration as a constriction and adjustment that altered the meaning of the word 'physics' in an unfortunate way. And perhaps the point on which they disagreed most strongly was scientists' self-perception of epistemic autonomy. Kevles believed that scientists were able to use their positions close to the center of executive power both to influence defense policy and "to represent the interests of the civilian-defense-science-enterprise." Forman believed that the "civilian-defense-science" was *precisely* what they represented, even while insisting, falsely, that they were representing unbounded "science."

Today few historians would consider the notion of unbounded science to be very useful; science, most of us would argue, is bounded, supported, sustained, and constrained by all the same social forces that bound, support, sustain, and constrain other human activities. Yet such a broad generalization only takes us so far, because we want to know how changes in human society change the activity we call science and the knowledge and insights that activity yields. We are also interested in how changes in scientific concepts and understandings change society. Whether or not scientific and technical knowledge was substantially responsible—through the agency of nuclear weaponry—for starting the Cold War, there is little doubt that science and technology enabled the arms race that became and sustained its center. Conversely, there is little doubt that science as we know it today was created in the Cold War, and that the Cold War expansion of science and technology continues to ramify through contemporary life.

Notes

1. P. M. S. Blackett, *Military and Political Consequences of Atomic Energy* (Whittlesey House, 1949), 120; Blackett, *Fear, War and the Bomb: Military and Political Consequences of Atomic Energy* (Whittlesey House), 139. This quotation has been repeated many times—see, e.g., Mary Jo Nye, *Blackett: Physics, War and Politics in the Twentieth Century* (Harvard University Press, 2004), 89.

2. For a recent discussion of the role of the atomic bomb in the early Cold War, see Michael Gordin, *Red Cloud at Dawn: Truman, Stalin, and the End of the Atomic Monopoly* (Farrar, Straus and Giroux, 2009).

3. Martin J. Sherwin, *A World Destroyed: Hiroshima and Its Legacies* (Stanford University Press, 2003); Richard Rhodes, *The Making of the Atomic Bomb* (Simon & Schuster, 1986); Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (Simon & Schuster, 1995); Gar Alperovitz, *The Decision to Use the Atomic Bomb* (Vintage Books, 1996); Gordin, *Red Cloud at Dawn*.

4. George Orwell, "You and the Atomic Bomb," *Tribune*, October 19, 1945.

5. See Rhodes, *Making of the Atomic Bomb*, esp. 592–593 and 599–603.

6. Blackett, *Military and Political Consequences*, 3.

7. See Blackett, *Military and Political Consequences*, 7–8: "The theme that atomic bombs are dangerous that humanity should be prepared to forego the advantages of atomic power in order to save itself from destruction by atomic bombs is being energetically propagated today in America." On the other hand, we could also argue that the same hysteria provided the justification for the massive increase of US federal government support for science, viz., "the rapid expansion of scientific knowledge ... may reasonably be said to be a major factor in national survival." Secretary of War Robert P. Patterson, quoted in Paul Forman, "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940–1960," *Historical Studies in the Physical and Biological Sciences* 18 (1987): 149–229 (156, note 10).

8. Blackett, *Military and Political Consequences*, 141.

9. Ibid.

10. Famously by Herman Kahn in *Thinking about the Unthinkable* (Horizon, 1962) and later by various neo-conservatives such as Richard Perle (Herb York, personal communication.) Recently the argument was revived by several leading NATO generals—see Ian Traynor, "Pre-emptive Nuclear Strike a Key Option, NATO Told," *Guardian*, January 21, 2008. With breathtaking illogic, the generals asserted that "the first use of nuclear weapons must remain in the quiver of escalation as the ultimate instrument to prevent the use of weapons of mass destruction." See also Naomi Oreskes and Erik M. Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (Bloomsbury, 2010), chapter 2. The nuclear-

winter debate of the 1980s was fought against a backdrop of discussions of a "winnable" third world war.

11. On the Cold War beyond the US–USSR axis, see Odd Arne Westad, *The Global Cold War: Third World Interventions and the Making of Our Times* (Cambridge University Press, 2005).

12. Walter LaFeber, *America, Russia, and the Cold War, 1945–1996* (McGraw-Hill, 1997). It is difficult to say how much of the darkness of the Soviet period was a result of the Cold War and how much an extension of the long history of repressive government in Russia. Historians have noted the discrepancy between the image of the Soviet Union promulgated by Orwell and other Western Cold Warriors and the realities, which, while troublesome, were far from monolithically dark. Certainly, in the realm of science, a great deal of interesting and important work was supported. Besides the essays by Schmid and Siddiqi in this volume, see Alexei Kojevnikov, "Rituals of Stalinist Culture at Work: Science in Intraparty Democracy circa 1948," *Russian Review* 57, no. 1 (1998): 25–52; Alexej Yurchak, *Everything Was Forever Until It Was No More: The Last Soviet Generation* (Princeton University Press, 2006). Similarly, American McCarthyism and other Cold War anxieties had clear precedents in the nativist and anti-communist attitudes of earlier red scares, the Palmer Raids, the Smith Act, etc. American anti-communism didn't begin during the Cold War, although the Cold War certainly exacerbated it. See Paul Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (Pantheon, 1985).

13. Of course, the Cold War altered many aspects of life, not only in the US and the USSR, but also in the European countries that offered the terrain where a third world war might be fought, in the Asian countries in which proxy wars were actually fought, and in developing nations viewed by the superpowers as prizes to be won in a global competition. But science played a role in the Cold War that music and dance did not—although scholars have shown how even music and dance weren't immune from Cold War considerations. See, e.g., Frances Saunders, *The Cultural Cold War: The CIA and the World of Arts and Letters* (New Press, 1999. Recently, scholars have begun to pay attention to sports as a playing field (pun intended) of Cold War competition. Stephen Wagg, David Andrews, and Robert Edelman, eds., *East Plays West: Sport and the Cold War* (Routledge, 2007).

14. The exact number of ballistic missiles depends on how you count (there are, for example, ICBMs, SLBMs, and intermediate-range missiles, and there is the problem of MIRVs), but SALT II limited strategic forces to 2,250 of all categories of delivery vehicles on both sides. See the introduction to Stephen I Schwarz, *Atomic Audit: The Costs and Consequences of U.S Nuclear Weapons since 1940* (Brookings Institution Press, 1998). On the history of attempts to control the arms race, see Committee on International Security and Arms Control, US National Academy of Sciences, *Nuclear Arms Control: Background and Issues* (National Academy Press, 1985).

15. President Dwight D. Eisenhower, farewell address, January 17, 1961 (http://www.ourdocuments.gov/doc.php?flash=true&doc=90).

16. "Dwight D. Eisenhower, From a speech before the American Society of Newspaper Editors, April 16, 1953" (http://www.quotationspage.com/quotes/Dwight_D._Eisenhower/).

17. LaFeber, *America, Russia*, 1.

18. Michael Gordin has recently emphasized that many "national" nuclear weapons programs were actually cooperative endeavors; for example, the Manhattan Project involved British and Canadian cooperation and many European émigré scientists. (See Gordin, *Red Cloud at Dawn*, esp. introduction and p. 121.) On the compunction felt by other nations to "be nuclear," see Gabrielle Hecht, *The Radiance of France: Nuclear Power and National Identity after World War II* (MIT Press, 1998); Hecht, *Being Nuclear: Africans and the Global Uranium Trade* (MIT Press, 2012).

19. Rhodes, *Making of the Atomic Bomb*; Sherwin, *A World Destroyed*; Gordin, *Red Cloud at Dawn*; Silvan S. Schweber, *In the Shadow of the Bomb: Bethe, Oppenheimer, and the Moral Responsibility of the Scientist* (Princeton University Press, 2000); Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm, 1870–1970* (Viking, 1989).

20. Sherwin, *A World Destroyed*.

21. Boyer, *By the Bomb's Early Light*.

22. Gordin, *Red Cloud at Dawn*.

23. Westad, *The Global Cold War*.

24. John L. Gaddis, *The United States and the Origins of the Cold War, 1941–1947* (Columbia University Press, 1972). See also Gaddis, *The Cold War A New History*, new edition (Penguin, 2005).

25. Gaddis, *The United States and the Origins of the Cold War*, 2.

26. Ibid.

27. On the former, see Sherwin, *A World Destroyed*. On the latter, see Alperovitz, *Decision to Use the Atomic Bomb*.

28. LaFeber, *America, Russia*, 1.

29. Ibid., 1–2.

30. Here I follow LaFeber's *America, Russia*, one of the classic American sources on this issue. More recently, David Engerman has emphasized a contrasting point: that many American intellectuals romanticized the Russian modernizing model and closed their eyes to the (emerging) human costs. See David C. Engerman, *Modernization from the Other Shore: American Intellectuals and the Romance of Russian Development* (Harvard University Press, 2004). My own view is that these two perspectives are complementary rather than conflicting.

31. Quotations from LaFeber, *America, Russia*, 8.

32. LaFeber, *America, Russia*, 17. See also William I. Hitchcock, *The Bitter Road to Freedom: A New History of the Liberation of Europe* (Free Press, 2008).

33. LaFeber, *America, Russia*, 11.

34. Ibid., 23–25, Sherwin, *A World Destroyed*; Rhodes, *The Making of the Hydrogen Bomb*.

35. LaFeber, *America, Russia*, 24.

36. Michael Dennis, A Change of State: The Political Cultures of Technical Practice at the MIT Instrumentation Laboratory and the John Hopkins University Applied Physics Laboratory, 1930–1945, PhD dissertation, Johns Hopkins University, 1991.

37. Although science was enlisted in the Cold War, so were industry, labor, economics, Hollywood, and just about everything else. In that sense, the Cold War truly was a total war.

38. See Daniel J. Kevles, "Cold War and Hot Physics: Science, Security, and the American State, 1945–1956." *Historical Studies in the Physical and Biological Sciences* 20 (1990): 239–264; Paul Forman, "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940–1960," *Historical Studies in the Physical and Biological Sciences* 18 (1987): 149–229; Hugh Gusterson, *Nuclear Rites: A Weapons Laboratory at the End of the Cold War* (University of California Press, 1996); Peter Galison, *Image and Logic: A Material Culture of Microphysics* (University of Chicago Press, 1997); Peter J. Westwick, *The National Labs: Science in an American System, 1947–1974* (Harvard University Press, 2003); Laurie Brown and Lillian Hoddeson, eds., *The Birth of Particle Physics* (Cambridge University Press, 1983); Robert Seidel, "A Home for Big Science: The Atomic Energy Commission's Laboratory System," *Historical Studies in Physical and Biological Sciences* 16 (1986): 135–175; Robert Seidel, "The Postwar Political Economy of High Energy Physics," in *Pions to Quarks: Particle Physics in the 1950*s, ed. Laurie Brown, Max Dresden, and Lillian Hoddeson (Cambridge University Press, 1989); Robert Seidel, "From Glow to Flow: A History of Military Laser Research and Development," *Historical Studies in the Physical and Biological Sciences* 18 (1987): 111–147.

39. No comprehensive history of the National Institutes of Health has been published, but some relevant material can be found in the following works: Buhm Soon Park, "The Development of the Intramural Research Program at the National Institutes of Health after World War II," *Perspectives in Biology and Medicine* 46, no. 3 (2003): 383–402; Park, "Disease Categories and Scientific Disciplines: Reorganizing the NIH Intramural Program, 1945–1960," in *Biomedicine in the Twentieth Century: Practices, Policies, and Politics*, ed. Caroline Hannaway (IOS Press, 2008). See also Advisory Committee on Human Radiation Experiments, *The Human Radiation Experiments: Final Report of the President's Advisory Committee* (Oxford University Press, 1996).

40. Sheila Jasanoff, ed., *States of Knowledge: The Co-Production of Science and Social Order* (Routledge, 2004). See also Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbs, Boyle, and the Experimental Life* (Princeton University Press, 2011).

41. And, conversely, how and why that context didn't produce other knowledge, either deliberately or inadvertently. See Robert Proctor and Londa Schiebinger, eds., *Agnotology: The Making and Unmaking of Ignorance* (Stanford University Press, 2008).

42. Paul Forman, "Weimar Culture, Causality, and Quantum Theory: Adaptation by German Physicists and Mathematicians to a Hostile Environment," *Historical Studies in the Physical Sciences* 3 (1971): 1–115. Forman expanded on his original argument in "*Kausalität, Anschaulichkeit,* and *Individualität*, or How Cultural Values Prescribed the Character and Lessons Ascribed to Quantum Mechanics," in *Society and Knowledge*, ed. Nico Stehr and Volker Meja (Transaction Books, 1984).

43. Forman, "Weimar Culture," 268.

44. Cathryn Carson, Alexi Kojevnikov, and Helmuth Trischler, eds., *Weimar Culture and Quantum Mechanics: Selected Papers by Paul Forman and Contemporary Perspectives on the Forman Thesis* (Imperial College Press, 2011), 225.

45. Forman, "Weimar Culture," 63.

46. "Paul Forman," http://americanhistory.si.edu/profile/399. See also Carson, Kojevnikov, and Helmuth, *Quantum Mechanics and Weimar Culture*.

47. Forman, "Behind Quantum Electronics"; Paul Forman and José M. Sánchez-Ron, eds., *National Military Establishments and the Advancement of Science and Technology: Studies in 20th Century History* (Kluwer, 1996), 272–275 and note on 316. Forman didn't invent the word 'gadgeteering', but he highlights it as an actor's category and not necessarily an approbative one.

48. Forman, "Behind Quantum Electronics," 152, quoting the physicist Jerrold Zacharias.

49. There were notable exceptions. For an interesting negative appraisal of the role of military funding from within the physics community, see Vera Kistiakowsky, "Military Funding of University Research," *Annals of the American Academy of Political and Social Science* 502 (March 1989): 141–154. Biologists, too, expressed concerns about whether the model provided by physics was appropriate for their work; see Elena Aronova, Karen Baker, and Naomi Oreskes, "From the International Geophysical Year through the International Biological Program to LTER: Big Science and Big Data in Biology, 1957–present," *Historical Studies in the Natural Sciences* 40, no. 2 (2010): 183–224. Scientific ambivalence toward Big Science is taken up by Steven Shapin in *The Scientific Life: A Moral History of a Late Modern Vocation* (University of Chicago Press, 2010).

50. For a discussion of some of the contradictions inherent in this framework, see Naomi Oreskes, "Science, Technology, and Free Enterprise," *Centaurus* 52 (2010): 297–310, an essay inspired by John Krige's book *American Hegemony and the Postwar Reconstruction of Science in Europe* (MIT Press, 2008). See also John Krige, "NATO and the Strengthening of Western Science in the Post-Sputnik Era," *Minerva* 38, no. 1 (2000): 81–108.

51. Erwin Chargaff, *Heraclitean Fire: Sketches of a Life before Nature* (Rockefeller University Press, 1978).

52. The allegation that this was in fact happening would later become the justification for the Mansfield Amendment to limit military funding to research that directly supported military priorities.

53. Forman, "Behind Quantum Electronics," 194. On education, see John Rudolph, *Scientists in the Classroom: The Cold War Reconstruction of American Science Education* (Palgrave, 2002).

54. Forman, "Behind Quantum Electronics," 193–194.

55. Ibid., 198. On the growth of scientific manpower, see David Kaiser, "Cold War Requisitions, Scientific Manpower, and the Production of American physicists after World War II." *Historical Studies in the Physical Sciences* 33 (fall 2002): 131–159.

56. Forman, "Behind Quantum Electronics," 200.

57. Ibid., 209. The internal quotation is from remarks by Harvey Brooks on the occasion of the twentieth anniversary of the Office of Naval Research.

58. I am not suggesting this is unique to the realm of military patronage. Consider, for example, Robert Kohler's discussion of Rockefeller Foundation support for science in *Partners in Science: Foundations and Natural Scientists, 1900–1945* (University of Chicago Press, 1991). See also Kai-Henrik Barth, "The Politics of Seismology: Nuclear Testing, Arms Control, and the Transformation of a Discipline," *Social Studies of Science* 33, no. 5 (2003): 743–781.

59. Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (MIT Press, 1996), chapter 3.

60. Forman, "Behind Quantum Electronics," 209–210, quoting from Harvey Brooks on twentieth anniversary of ONR; Naomi Oreskes, "A Context of Motivation: US Navy Oceanographic Research and the Discovery of Sea-Floor Hydrothermal Vents," *Social Studies of Science* 33, no. 5 (2003): 697–742.

61. An interesting example of this occurred in the 1960s when the Canadian marine biologist Frederick Aldrich proposed an investigation of the enigmatic giant squid using the submersible *Alvin*. The giant squid was one of the very subjects that had been used in the 1960s in the proposal to construct *Aluminaut*—an early submersible—in outlining its potential basic science applications, but the project was rejected on the grounds that it didn't fall under the mission profile under which *Alvin* was funded by the ONR. See Naomi Oreskes, *Science on a Mission: American Oceanography from the Cold War to Climate Change* (University of Chicago Press, forthcoming), chapter 6.

62. Forman, "Behind Quantum Electronics," 224.

63. See also Schweber's discussion of this point in *In the Shadow of the Bomb*.

64. Kevles, "Cold War and Hot Physics."

65. Ibid., 240.

66. Part of the problem arises from the very term "basic science." After all, what does it mean to refer to "basic research related to the development of guided missiles," or the "basic microwave research of the [MIT] Radiation Laboratory," when the Rad Lab's primary purpose was to advance the development of radar? See Kevles, "Cold War and Hot Physics," 242–244.

67. Kevles, "Cold War and Hot Physics," 241.

68. Ibid., 241.

69. Ibid., 263.

70. Ibid., 264.

71. Forman, "Behind Quantum Electronics," 152.