Essays on

TWENTIETH CENTURY HISTORY

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The Technopolitics of Cold War

Toward a Transregional Perspective

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Technological change played a major role in the defining events of the twentieth century, especially in war. Two world wars, the cold war, and colonial and postcolonial conflicts around the globe were all characterized by innovation in the technologies of destruction, from tanks and ballistic missiles to mass-produced automatic rifles and portable antiaircraft rockets. As the century wore on, conflicts spread well beyond the battlefield. Weapons of mass destruction rendered specious most distinctions between military fronts and protected rear areas. Mass production dropped the price of small arms into the bargain basement, while free markets made them readily available.

Across nearly four decades of cold war, military hardware became an economic sector unto itself. By the mid-1980s, global annual military budgets reached nearly $1 trillion. This figure included almost $350 billion in global annual expenditure on weapons and military hardware, but ignored untold billions in arms trade on a global black market.[1] Notions of a "military-industrial complex"—already a commonplace in the early 1960s—only hinted at the depth of the entanglements between technology, military power, political authority, and civil society that had developed by the cold war's end.

Perhaps precisely because these entanglements are so salient, historians rarely try to explain the course of technological change itself. Recent scholarship on globalization, for example, makes much of the idea that evolving transport and communication infrastructures promoted globalization processes.[2] But like most historiography, this scholarship usually treats technology as a hermetic "black box." Technology appears as an explanatory factor, yet rarely are the inner workings of technological innovation and diffusion tied directly

to what is being explained. Narratives and tropes of progress, widely discredited in political and social history, still find broad and unexamined acceptance with respect to technological change.

Nowhere has this been more striking than in studies of the cold war. Historians regard the superpower arms race as one of the cold war's central features. Yet outside the subspecialty of the history of technology, most have treated its military technology as an exogenous force. In such accounts, nuclear weapons appear as ready-made tools for politicians, end products of the byzantine military-industrial complex, or awe-inspiring sources of iconography. Politicians and diplomats figure as the most significant actors, and popular images of things nuclear constitute cold war culture. Until recently, this approach produced studies of the cold war focused primarily on so-called nuclear states (those possessing atomic weapons)—especially, of course, the United States and Soviet superpowers. Other parts of the world made an appearance primarily as proxy sites for superpower struggles, or thorns in the sides of the two titans.

Revisiting the Cold War: Technology and Transregional Perspectives

The traditional account of the cold war begins with the partition of Europe after World War II. Initially intended as a temporary custodial arrangement, the partition became quasi-permanent by 1947–1948, as the Soviet Union installed communist governments throughout Eastern Europe and the U.S.-backed Marshall Plan brought Western Europe under American influence. The U.S. policy of "containment" committed the United States to limiting the spread of communism by all possible means, anywhere in the world. The cold war became in rhetoric, and often in practice as well, a global, total contest between competing ideologies, economies, and cultures. With the first successful Soviet nuclear test and the Chinese communist revolution in 1949, closely followed by the outbreak of war on the Korean peninsula, tensions between the emerging superpowers escalated dramatically. An unprecedented arms race began in both conventional and new, high-tech weapons that included not only nuclear explosives but also jet aircraft, ballistic missiles, and nuclear-powered submarines.

The cold war continued with the Cuban Missile Crisis of 1962 and U.S. entry into the Vietnam conflict in 1965. In the 1970s, a period of détente ensued, but the nuclear arms race continued without a break. The Soviet invasion of Afghanistan in 1978 renewed tensions, initiating a period sometimes known as "Cold War II" or the "Carter-Reagan Cold War."[3] During this period, U.S. military budgets soared to dramatic heights, even as popular protests against nuclear weapons intensified. In 1985, Mikhail Gorbachev came to power, restructuring the Soviet economy and relaxing restrictions on political speech. By some accounts, this ultimately led to the collapse of the Soviet

Union in 1991. Many historians date the cold war's end to the dismantling of the Berlin Wall in 1989, following the collapse of the East German communist regime, part of a wave of democratic quasi-revolutions in Eastern Europe during that year.

Recently, historians have called for reexamining the cold war from perspectives that reduce the centrality of the superpower struggle. The dominance of cold war politics probably led contemporaries to focus too closely on its largest military actors, namely the United States, Europe, and the Soviet Union. From other points of view—especially that of the global South—processes such as decolonization and development were more salient. Historians have begun to move beyond treating the South merely as proxy sites for cold war conflicts, instead exploring how national politics and culture in places like Vietnam and Algeria shaped cold war practices "from below." This approach is becoming known as the "new international history."[4] It provides important new perspectives, but still does not examine the role of technology in global conflict.

One area of social science scholarship *has* endeavored to include technological change as an object of analysis: "science and technology studies," or STS. This field includes historians, sociologists, anthropologists, and others interested in understanding technological systems and their relationship to social, political, and cultural dynamics. STS has devoted considerable attention to cold war science and technology, but this too has generally centered on the United States, Europe, or the Soviet Union. Because they seek to unpack the inner political and social workings of technology, these scholars tend to focus on case studies and microprocesses. The macroview offered by global and transregional history is nearly nonexistent in this literature.

This chapter, then, aims to put two scholarly fields in dialogue in order to explore cold war technopolitics in a transregional perspective. We hope thereby to stimulate new ways of teaching about and conducting research on the cold war. First, we survey the political and social history of cold war technology. Second, and simultaneously, we seek to improve our understanding of cold war technopolitics by approaching them from a transregional point of view. Due to space constraints, we focus here on just two technical systems: nuclear technologies and computers. These comprise our areas of expertise, but they also represent two of the cold war's most significant technological systems (the third being space and missile technologies, which we can only treat in passing).

ANALYZING TECHNOLOGICAL CHANGE

For our purposes, foremost among the tools of STS is the *sociotechnical systems approach* developed by Thomas Parke Hughes and his colleagues.[5] This perspective directs us to view technologies not as individual devices, but as vast, interdependent networks of artifacts, institutions, people, and social systems. The nuclear system thus includes not only warheads and reactors but

also uranium mines, missiles, electric power grids, weapons testing sites, and waste disposal facilities. It also includes regulatory agencies, national laboratories, corporations, military commanders, scientists, technicians, and miners, as well as communities located near mines, reactors, waste dumps, and nuclear missile silos. Similarly, as sociotechnical systems computers include not only central processors but also peripheral devices (printers, disk drives, and so forth), software corporations, manufacturing facilities, maintenance technicians, geographical clusters and cultures such as Silicon Valley, the all-important system operators who manage networks, data-entry workers, chip manufacturers, and software developers are located all over the world. Indeed, computers and computerized networks—not only the Internet, but others such as those of the major credit card systems, banks, and financial markets—have become fundamental infrastructures in the developed world, with tendrils reaching around the globe. From this perspective, devices, institutions, and altered social relations form a complex sociotechnical system, where causal relationships look more like mutual construction than like technological determinism.

Properly deployed, the sociotechnical systems approach can help trace links between apparently unconnected historical actors, such as American nuclear weapons designers and the Congolese hard-rock uranium miners who supplied their raw materials. Where the former derived enormous power from their technical knowledge and technological resources, the latter suffered from their lack. How do actors derive power from technical knowledge? In what does their power consist? Familiar historical categories such as race, class, institutions, and culture can help explain these relations. But they are not enough. In sociotechnical systems, power derives from the control of knowledge, artifacts, and practices. This hybrid form of power has cultural, institutional, and technological dimensions. We call it "*technopolitics.*"[6]

Technopolitics is the strategic practice of designing or using technology to enact political goals. Such practices are not simply politics by another name. They produce artifacts whose design features matter fundamentally to their success, and to the ways in which they act upon the world.

When political actors work with engineers to solve problems, such as how to manage the command and control of nuclear-armed military forces on a global scale, they orient each other to particular solutions. As politicians and designers work together—very often indirectly, mediated through institutions—emerging technical capabilities both create and constrain political possibilities. At the same time, technical capabilities expand and take on directionality to the extent that they acquire political support and effectiveness; unsupported designs come to seem impractical (even if they are not) once large resources have been committed to another alternative.

Very often, if not always, neither politicians nor engineers foresee the full implications of this process, which we call "*mutual orientation.*"[7] For example, during the cold war, both the United States and the Soviet Union constructed

global systems to provide early warning of nuclear attack. As warning time windows shrank to mere minutes, both sides automated these systems and preprogrammed their military responses. A major technopolitical implication foreseen by neither side was that these highly automatic warning systems effectively became tightly coupled to each other. Military activity by one side provoked an immediate response from the other; this could produce a rapid series of upward-ratcheting movements that very nearly led to accidental nuclear war on a number of occasions.[8]

This chapter deploys these ideas in its survey of scholarship on the nuclear age and the computer age. World War II military projects boosted nuclear technologies and digital computers from prototype to operational systems. In the immediate postwar period, military development continued to dominate both systems. They soon grew closely connected, as computerized control made possible global nuclear command and unintentionally integrated the superpowers into a single, tightly coupled cybernetic unit: apocalypse on a hair trigger. Starting in the 1950s, national governments began to invest heavily to advance their civilian applications.

At that point, the histories of nuclear systems and computers began to diverge. After enjoying a "bandwagon market" in the 1960s, orders for nuclear power reactors began to drop off. Until very recently, only a few nations envisaged building new ones. Nuclear power has remained a system that can operate only on a very large scale, with massive state involvement. Despite the best efforts of civilian manufacturers, nuclear power could not seem to shed its symbolic ties to nuclear weapons. In contrast, computers rapidly managed to cast off the symbolic baggage of military association. They enjoyed spectacular commercial success in the 1960s, when they too were an expensive "big technology," attractive mainly to large corporations and governments. Several commercial booms ensued and in the 1980s, desktop "personal" computers became consumer products and corporate computer networks laid the groundwork for the modern Internet. So despite the continuing significance of military computing, the profound success of computers as commodities ultimately brought them out from under the shadow of their original military sponsors.

Five decades ago, both nuclear power and computers were the subjects of utopian visions. Power would be "too cheap to meter." Robots would run our factories and artificial minds would solve our problems. By the 1970s, economic and technical problems, environmental hazards, and major social movements had shattered nuclear utopianism. But cyber-utopianism shook off every fear, gathering strength even into the present. Whereas nuclear technologies proved mainly divisive, computer technologies emerged—at least in the popular imagination—as a global unifying force and a symbol of libertarian freedom.

We divide our discussion of these developments into three thematic sections. First, we examine the arms race, a central technopolitical dynamic of the cold war in which nuclear and computer systems were closely intertwined.

Second, we explore the complex relationships among expertise, power, and democracy that characterized nuclear and computer technopolitics in the cold war. Third, we address the ways these technopolitics were involved in the reshaping of nationalisms, colonialisms, and international relationships.

Our survey is by no means exhaustive. Instead, we have chosen works that, when grouped together, can help scholars and teachers develop fresh perspectives on the role of technology in the cold war. We have taken an interdisciplinary approach, including not only history but also sociology, anthropology, and political science as appropriate. We have endeavored when possible to offer comparative perspectives on nuclear and computer history, but the current state of historiography severely limits our efforts: computer history in particular is dominated by U.S. material. We can only hope that the holes in our survey will inspire future studies of technopolitical systems in transregional perspective.

Technopolitics and the Arms Race

The U.S.-Soviet arms race constituted the central technological and military dynamic of the cold war. Not only among historians but also among the lay public, considerable controversy still rages around its origins. One passionate debate concerns the U.S. decision to drop atomic bombs on Hiroshima and Nagasaki. Were these bombs necessary to end the war? Did the U.S. nuclear attack initiate the cold war, or did the Soviet Union start it during the Allied occupation of Europe? This well-trodden historical terrain underlies many investigations of cold war technology, often driven by the all-important question: was the arms buildup necessary to prevent a World War III?[9]

Though ultimately unanswerable, this counterfactual question nonetheless provides a key entry point into any analysis of arms-race technopolitics. The United States alone spent $5.8 trillion developing the complex technological systems—from missiles and submarines to computers and communications satellites—required to support its nuclear arsenal.[10] The public rationale for most of these expenditures was that this arsenal guaranteed the security not only of the United States but also of Europe and even the entire globe, by "deterring" the USSR from using its own arsenal to achieve its expansionist aims.

In fact, national security was only one among many factors driving weapons development and deployment. Others included interservice rivalry, "technological enthusiasm," national prestige, and the entrenched interests and routines of the military-academic-industrial "Iron Triangle."[11] These forces not only guided decisions about how many and what kind of weapons to build but also shaped the design of weapons and delivery systems, sometimes in unexpected ways.

Consider the following example. In the 1950s, the United States constructed the world's first computerized continental air defense system, to track and

shoot down nuclear-armed Soviet bombers. At the time, most engineers believed that computers were far too slow and too unreliable to do the job. Why, then, deploy them for this difficult and ultraimportant task?

The answer reveals a complex technopolitical choice. Charged with finding technological solutions to the defense of an entire continent, rival groups of civilian engineers advocated different solutions. One involved new, high-risk digital computer technology, while the other promised to automate and improve the existing slow but reliable analog systems. Frightening intelligence estimates of Soviet technological capabilities created a powerful sense of urgency. Although these estimates turned out to be overblown, they generated pressure for radical change and helped promote massive investment in new technology. Public anxiety about a possible Soviet surprise attack led politicians to promise active air defense. Behind the scenes, though, no knowledgeable officer expected any air defense to shoot down more than 20 percent of enemy bombers. Meanwhile, air force "prompt use" strategy—known only to commanders at the highest levels—assumed that the United States would strike first, destroying Soviet bombers before they left the ground and rendering air defense unnecessary.[12]

The initial proposal for a computerized warning system came not from the military, but from civilian engineers at the Massachusetts Institute of Technology (MIT), whose existing computer project was threatened by a funding crisis. Seeking a new sponsor, these engineers generated a blue-sky proposal for a centralized, computerized system for early warning, tracking, and interceptor control.[13] Within the air force, debates raged over the new idea, which would consolidate command of aircraft in control centers on the ground. Many officers resisted removing air defense from the hands of pilots. They also distrusted then new and untested computer technology. Far from being a foregone conclusion, the eventual decision to proceed with the computerized SAGE (Semi-Automatic Ground Environment) system represented a simultaneously technological, political, and ideological choice.[14] Among its immense ramifications was the award of a contract for the forty-six enormous SAGE computers to IBM. This contract played a decisive role in IBM's ascent to dominance of the world computer market in the 1960s.[15]

Or take a second example, from the second decade of the arms race: the U.S. development of missile guidance technologies in the 1960s. One might assume that perfecting nuclear weapons inevitably required increasing the accuracy of missiles. In fact, however, more accurate missiles were by no means an obviously desirable goal; increased accuracy had major strategic and economic implications. Early nuclear strategy derived from World War II carpet bombing of cities, designed not only to destroy weapons factories but also to kill and terrorize civilian populations. Yet highly accurate missiles could potentially destroy the opponent's missiles, even in hardened silos before they could be launched. Targeting missile silos rather than cities allowed strategists

to make the politically useful claim that theirs was a genuine military strategy, rather than simple terrorism. At the same time, it meant that one side's surprise attack could, in principle, eliminate the other's retaliatory capability and "win" a nuclear war. This encouraged the hair-trigger "use 'em or lose 'em" policy of "launch on warning." Thus, political factors largely unrelated to U.S.-Soviet relations shaped missile guidance technology. In turn, engineers and military leaders used this politically shaped technology to redesign nuclear strategy and lay claim to the expertise required to defend the Western world. In this manner, guidance systems were technopolitical: technologies designed to fulfill particular political purposes. Their politics, however, were often unremarked, even obscured: experts framed their designs as technological imperatives, the result of the inevitable path of technological progress.[16]

Obscuring the political dimensions of such technological changes, long-standing beliefs about industrial capitalism merged seamlessly with the liberal democratic ideologies driving the cold war in the West. Since at least the nineteenth century, U.S. discourse on technological development had emphasized ingenuity, entrepreneurship, and the free market: superior technology equated directly with marketplace success, and vice versa. American scientists and engineers, generally held in enormous esteem after their decisive roles in World War II, garnered further legitimacy and authority by distancing themselves from "politics." They pictured science as a disinterested search for truth, and technology as its practical application. Technology itself was "value-neutral"; only its users could determine its application for good or for ill. (Nonetheless, technology's association with science almost always gave it a positive valence by default.) On this distinctively American view, technological change involved politics only when its designers *explicitly stated* political or ideological goals. Notions of efficiency and progress, frequently invoked to justify technological change, were naturalized along with the liberal market capitalism that provided their motive force. This was the ideological backdrop that made it possible for air defense or missile guidance to appear apolitical in the United States.[17]

Nuclear Weapons and Computing
in the Soviet Bloc

American nuclear technopolitics may therefore surprise some readers, but findings that Soviet nuclear technology was politically shaped will shock no one. Cold war discourse framed the United States as apolitical, and the Soviet Union as profoundly ideological; it therefore followed that its technologies would have deeply political dimensions and be fundamentally "flawed" as a result. Recent scholarship makes clear that this opposition—political versus apolitical—is not a useful one in distinguishing between American and Soviet

technological developments. Both were the result of technopolitical processes, albeit in different ways.

As soon as Stalin had grasped the military implications of the Hiroshima and Nagasaki bombs, he gave the Soviet atomic weapons project top priority. Obsessed with the conflict between socialism and capitalism, Stalin isolated Soviet scientists from their Western colleagues. Thus, Soviet scientists and engineers designed nuclear weapons largely on their own (although spies like Klaus Fuchs sometimes provided useful technical knowledge). Under Stalin, a "command-administrative" structure guided development strategies. With his approval, the administrator in charge of this structure directed scientists and engineers to pursue numerous design alternatives simultaneously—against their better judgment—in order to build weapons as quickly as possible. The Stalinist regime's political practices reverberated throughout the Soviet nuclear system, most notoriously in the use of prison labor at uranium mines and construction projects.[18]

After Stalin's death, Khrushchev's administration sought a more open approach to scientific and technical development. This approach not only encouraged increased international contact but also enabled scientists and engineers to be more active in setting policy agendas for nuclear development. Specific information on weapons systems remains scarce, but a recent study of Russian nuclear power suggests ways that the Soviet system gave nuclear development a distinctive technopolitical profile. Party officials regarded nuclear power as the means to build a fully communist society: nuclear technology could revive "poorly performing" industries, for example, and irradiating foods could compensate for inefficiencies in agriculture. Soviet visions of nuclear panaceas thus resulted in what one author has labeled "atomic-powered communism."[19]

Cold war technopolitics was equally evident in the Soviet bloc's approach to computerization. By the late 1940s, Soviet engineers (here, too, isolated from their Western counterparts) had developed their own, largely independent line of computer research.[20] A small indigenous computer industry developed, but by the late 1960s, the prevalent approach involved functional copying and/or direct acquisition of Western technology, especially IBM machines. Ultimately, Soviet production and use of computers always lagged well behind the United States, Europe, and Japan. While much remains to be learned about the reasons for this major difference in technological orientation, informed speculation in recent scholarship suggests that technopolitics played a decisive role.

Even today, computerization is never a simple choice about machinery. Instead, it always represents a complex repositioning of the division of labor between human beings and machines. This can affect how work tasks are understood, organized, and executed at every level, from individuals to large institutions.[21] This was especially true in the 1950s, when the full capabilities of digital computers remained unexplored and their limitations were unknown.[22] During that period, the Soviet military apparently made a deliberate decision

not to pursue the rapid and far-reaching computerization of command and control systems characteristic of its U.S. counterpart.[23] Only when Khrushchev ordered substantial cuts in military personnel and conventional weapons in the early 1960s did military commanders begin to integrate computers into guidance systems. Even then, "computers were used largely to control weapons, not in command-and-control systems. In the latter field, introduction of computers would have upset existing information circulation patterns and threatened existing power structures," according to Slava Gerovitch.[24]

Another factor was the slow realization that the truly difficult problems of computing did not regard hardware, but problem definition and software coding and debugging. As one Russian military expert has written, in the 1950s, "heads of military system projects generally focused their attention on hardware development. . . . They took software development too lightly, did not allot necessary specialists and time, were not eager to estimate the necessary investments and resources. Programmers' labour was deemed to be very simple and cheap." Yet, ultimately, the cost of programming complex military systems far exceeded that of the computers themselves.[25] By the 1970s, about 100,000 programmers worked for the Soviet military forces. Thus—as was also the case with nuclear technologies—the full costs and implications of the entire sociotechnical system of computing became clear only slowly. Although Soviet military forces took full advantage of computers by the 1970s, economic constraints, limits on available expertise, poorly organized computer manufacturing infrastructure, and the politics of existing command-control structures interacted to restrict the role of computing in Soviet command-control systems.

One result of this technopolitical construction of computing was that until the late 1960s, the Soviets produced relatively small numbers of computers for civilian use. Experience with the machines was therefore acquired more slowly. Only in the late 1960s and early 1970s, with the Ryad series of mainframes, did the Soviets (together with their satellites) begin a serious attempt at widespread computerization.[26] This, too, was tied directly to ideology via the notion of "scientific-technological revolution," which Goodman has characterized as "perhaps the most important ideological extension of Marxism-Leninism since the early days of the USSR."[27]

In a wider global context, it is the ceaseless American efforts to dissociate technology from politics that appear anomalous—not the Soviet acknowledgment of their interplay. This is especially clear in nuclear weapons development: the engineers, scientists, administrators, and politicians who shaped the military atom outside the superpowers appeared fully aware of the technopolitical dimensions of this process.

Beyond the Superpowers: Nuclear Politics in France, Israel, and India

Arguing that U.S. nuclear capability would suffice to defend the Western world, American policy makers discouraged even their closest foreign allies from developing atomic bombs. But for Britain and France, more was at stake than simple security: a need for independence, anxieties about global status and decolonization, the prestige of nuclear scientists and engineers, and strong desires to develop modern scientific and technological infrastructures played important roles in their decisions to develop atomic weaponry. Britain exploded its first bomb in 1952; France in 1960. Other nations followed suit: China, Israel, South Africa, India, and Pakistan—to name only those with confirmed weapons programs. In all of these instances, the actual development and deployment of nuclear weapons came about through the sophisticated, self-conscious prosecution of complex technopolitics. In particular, a widespread tactic for pushing weapons programs through involved using ambiguities in engineering design to camouflage or shape political goals. We illustrate this point by considering weapons development in France, Israel, and India.[28]

France officially became the world's fourth military nuclear power in 1960, when it tested its first atomic bomb in the Algerian desert. The French appeared to have developed their bomb in record time, having announced their intention to do so a scant two years earlier. But examining French nuclear technopolitics reveals a longer history. At least as early as 1951, high-level engineer-administrators in the French Commissariat à l'Energie Atomique (CEA) expressed serious interest in developing atomic weaponry, partly to re-create a distinctive national identity after the traumas of World War II, partly to counter the transformation (and later, loss) of France's empire, and partly to secure independence from superpower wrangling. But the various prime ministers who led the country in the 1950s were unwilling to commit publicly to a military program. Rather than force the issue, CEA leaders adopted a versatile approach to civilian nuclear development by choosing a reactor design that could—at least in principle—produce both electricity and weapons-grade plutonium. Depending on the audience and the political climate, these reactors could be presented as purely civilian, purely military, or somewhere in between. CEA leaders skillfully deployed this flexibility to ensure continuity in the reactor program, as well as the *de facto* pursuit of a nationalist military nuclear policy well before the government was willing to commit to any such thing. The reactors thereby enacted policy in a way that classic political processes could not. When France officially announced its intention to build a bomb in 1958, CEA engineers were already well along the road. Thus, no

single moment marked the political decision to acquire a bomb—but nor did the French bomb grow inevitably out of an existing technological infrastructure.[29]

Similarly, Israeli nuclear weapons did not result from careful strategic planning, but rather from a sediment of small decisions responding to immediate political and technological circumstances. Indeed, similarities between Israeli and French nuclear development were not coincidental: in the 1950s, France shared not only reactor technology but also nuclear expertise with Israel. At the same time, Israeli nuclear leaders also learned the technopolitics of ambiguity, just as in 1950s France, Israeli nuclear decisions were made by the expert elites, not by politicians. But while French nuclear decision making shifted to include more classically political input in the 1960s, no such shift occurred in Israel. By 1970, "a tradition had been established which held that the political arena was not the appropriate forum in which to decide [Israel's] nuclear policy." Like the French, Israeli nuclear leaders claimed that their reactors—in reality, optimized for producing bomb-grade fuel—were prototypes for electrical generation. But Israel went much further, refining technopolitical ambiguity to a high art. For example, Israeli engineers did not test their atomic bombs, because the act of testing would have been tantamount to an official declaration that Israel "had the bomb." Such a declaration might only spur Arab neighbors to begin military nuclear development. Unlike France, Britain, and China (which all tested their bombs to establish great power status), Israel's particular circumstances suggested that a state of permanent technopolitical ambiguity would bring greater geopolitical benefit.[30]

For France and Israel, military nuclear capability was only partly motivated by national security. Similarly, two recent studies of India's nuclear program argue that national security provided only a thin justification for developing an atomic bomb. There, even more than in France and Israel, policy making remained in the hands of a small "strategic enclave" of scientists and engineers. In the 1950s and 1960s, the primary goal of these men was to put India on the international scientific and technological map. Like their counterparts elsewhere, they saw an independent nuclear program as a means of defining national identity.

Of course, newly independent India was in a radically different geopolitical position from other nuclear powers. Indian scientists and technologists believed that their nuclear work would shape their nation's postcolonial emergence through a distinctive hybrid of "science, modernity, and indigeneity."[31] The precise nature of that hybridity, however, remained open to debate. Some elites thought that India should distinguish itself from the West by taking the moral high ground, renouncing military nuclear capability. Others thought that India required the military atom to attain prestige commensurate with its size. Tensions and power struggles between these two camps meant that the Indian

bomb project proceeded in fits and starts. Thus, Indian leaders claimed that the 1974 test was a "peaceful nuclear explosion." Not until 1998 did the nation officially acknowledge—and test—its military nuclear capability. Throughout these decades, however, the symbolic utility of a nuclear bomb greatly outweighed any military value, since its most likely targets were Pakistan or China—making it impossible for India to use the bomb without risking severe damage on its own soil. Domestic factors outweighed national security needs, and indeed the nuclear elite kept the military removed from its development efforts. In the end, domestic rivalries, based partly in competition over who could count as an expert authority, shaped India's nuclear capability and the cultural meanings that surrounded it.[32]

Comparing these various programs highlights the close association between nuclear technology and national identity. At first glance, this may seem paradoxical. How could the same technology provide a distinctive emblem for several different nations? The answer lies in the hybrid, technopolitical nature of nuclear development. *How* technological choices were made matters as much as *which* choices were made. Responding to a variety of domestic problems, such as loss of prestige, wartime devastation, decolonization, or the need to establish a new state, technical and political elites sought to create distinctive national nuclear programs. This certainly did not mean that elites agreed on the character of national identity. Nuclear choices were often entangled with debates over how best to shape the nation, and over which institutions or social groups were best equipped to do the shaping. Nuclear debates regularly invoked symbols of nationalism, both old and new. The French compared reactors to the Arc de Triomphe; the Russians likened them to samovars; in China, leaders spoke of "the people's bomb."[33] In each of these cases, elites used the symbolic and material apparatuses of nuclear systems to perform new conceptions of national identity. Such nationalist discourse played an important role in marshaling domestic enthusiasm for costly nuclear projects in both the military and civilian spheres.

A SOCIOTECHNICAL SYSTEMS PERSPECTIVE ON NUCLEAR "SECURITY"

Rhetoric notwithstanding, then, nuclear weapons have typically served purposes well beyond national security. As George Perkovich argues, this point is crucial in the context of nuclear proliferation. Analysts who view states' interests in nuclear weapons solely in terms of national security miss crucial dimensions of their development—and thus are unable to even propose workable nonproliferation plans. Similarly, policy makers who fail to take seriously the technopolitical and cultural dimensions of nuclear development will never

produce anything more than fantasies about global disarmament (though these fantasies seem to have considerable popular appeal).

Have nuclear weapons made the world safer? Cogent arguments can be made that the fear of nuclear apocalypse, burgeoning along with the swollen superpower arsenals, deterred both sides from launching an intentional war. But the sociotechnical systems approach suggests that it is too simplistic to view nuclear weapons use as the product of clear decision-making processes by rational actors weighing purely political factors.

Consider the ghoulish combination of military and technopolitical logic that prevailed in the design of nuclear forces. In both the United States and the Soviet Union, political choices and absolutist ideologies dictated a global reach for national military power. Each side publicly portrayed its motives as purely self-protective. But military strategy had to take into account technological factors that gave an overwhelming advantage to a first-strike strategy. No effective defense against nuclear weapons was ever developed. Therefore, only an attack on delivery vehicles (first bombers, later missiles) *before they left the ground* could hope to prevent a catastrophic retaliatory strike. In the 1950s, General Curtis LeMay told a gathering of Strategic Air Command pilots that he "could not imagine a circumstance under which the United States would go second" in a nuclear war.[34] Nevertheless, official U.S. policy always proclaimed that the United States would never launch first.

By the early 1960s, three trends had emerged. Each side possessed thousands of thermonuclear warheads, making real the threat of near annihilation for the victims of an attack. Both superpowers could deliver those warheads using intercontinental ballistic missiles, capable of spanning the distance between them in half an hour; submarine-launched missiles could reach their targets in just ten minutes. Finally, computerized early warning and control systems placed the whole system on a hair trigger. The technopolitical logic of this situation made a first-strike strategy seem even more imperative. Paul Bracken has argued that during the cold war, "the likelihood of nuclear Munichs [was] exaggerated, but the possibility of nuclear Sarajevos [was] understated."[35] Other analysts concur that nuclear weapons arsenals actually "increased the likelihood of accidental war."[36]

Thus, the sociotechnical systems perspective provides deeper insight than a narrower view. Nuclear weapons alone do not make war more likely. But the nuclear weapons *system* does: hair-trigger, automatic warning and control systems; nonrecallable, ultrarapid delivery vehicles; and the social organization of command decisions. The operation of complex technopolitical systems is highly unpredictable, not because the technology has a life of its own, but because the systems are so deeply embedded in social, political, and cultural forms.[37] In the aftermath of the cold war, insufficient attention to nuclear technopolitics and their attendant unpredictability has taken on deadly dimensions. The dismantling of the Soviet Union has resulted in dubious security

structures for its nuclear weapons and materials; conflicts between India and Pakistan regularly raise the specter of nuclear war; and fears about nuclear "rogue states" provide a central theme for U.S. policy makers.

If American policy makers can successfully cast nuclear proliferation issues in narrow technical and security terms, it may well be because (as discussed earlier) the dominant discourse and practice surrounding technological development in the United States continually and actively divorces technology and politics. In order to understand this dynamic better, we turn to an analysis of the changing role of technical experts in modern states.

Expertise, Power, and Democracy

Modern states accorded key roles to technical experts long before the cold war.[38] Indeed, modernist forms of governmentality relied heavily on the creation of new state knowledge about citizens, from health and wealth to demography and geography; hence the birth of statistics.[39] Further links between technical expertise and state power developed when notions of "technocracy," or rule by technical experts, emerged in the late 1920s during the heyday of Fordism/Taylorism.[40] Although it rapidly acquired the antidemocratic connotations associated with oligarchy, technocracy originated in Progressive politics. It was seen as a way for states to guide social and technological change toward promoting the general welfare, *in opposition* to the privatized expertise represented by industry and benefiting only the industrial elite. Only state experts, asserted technocracy's proponents, could counter the increasing power of their industrial counterparts.

The power of technical experts in the modern state reached its zenith during the first decades of the cold war. In the United States and Soviet Union, wartime emergency arrangements rapidly became quasi-permanent peacetime collaborations between technology-based military forces, state-supported science research universities, and industrial laboratories.[41] From roughly 1945 to 1970, science enjoyed an aura of cognitive authority and infallibility, combined with a presumption of political and ethical neutrality. Attracted by the possibility of a privileged arbiter of truth, public officials and institutions including courts, regulatory bodies, and presidential advisors systematically and increasingly appealed to scientific expertise. This symbiotic relationship of scientific and political authority made expert advisors a veritable "fifth branch" of government.[42]

In what ways did technological development shape this "fifth branch"? First, it supported the growth of scientific knowledge, as the sciences required ever more complex, precise, and capable instruments and other tools. By automating scientific calculations, computers rapidly became a crucial tool in the growing infrastructure of "big science." In making possible the routine use of numerical simulations, they opened complex, nonlinear physical systems to

detailed investigation.[43] As the productive power of science grew, so too did its political prestige. Clearly, scientists controlled a new, ever more important means of (knowledge) production. Second, technology's own growth fed from this new knowledge, as both state and private laboratories increasingly systematized the use of science to create new products. By 1959, IBM began to reinvest more than half of its profits in research and development, a then unheard-of percentage that soon came to define the modern "high-technology" firm.

Third, technological development rapidly became the means and measure of cold war geopolitical power. The superpowers competed not only in the arms race but also in everything from the space race to the quality of home appliances, and other nations followed suit. This competition helped to entrench and increase the participation of experts in governance. Exports of technical expertise to the developing world, either directly or through training programs for foreign nationals, became a major means of establishing dependencies and alliances both for the superpowers, as part of this cold war competition, and for the former colonial powers, as a means of maintaining dominance in the postcolonial era. At the same time, scientific internationalism—the view of science as a single, unified international community "beyond" partisan politics—played an important role in damping cold war tensions.

The mounting reach and importance of new, complex, and sometimes dangerous technologies during the cold war sharpened debates about relations between technology and democracy. Conflicting attitudes about this relationship had long marked Western political traditions. Utopian political discourses often interpreted new technologies as a means to increase the rationality, transparency, and efficiency of democratic government. At the same time, dystopian discourses frequently viewed these same technologies as threats to democracy, seeing them as tools for surveillance, systems subordinating human needs to their cold logic, and vehicles for social domination by technocratic elites. Early cold war ideology relied on the temporary victory of the utopian view that successful technological development depended upon, produced, and guaranteed democracy. And democracy's greatest guarantor was a nuclear deterrent.

This perceived connection between technology and democracy helped to spur and to justify the proliferation of experts within the state, in the United States and elsewhere. Yet this very proliferation eventually served to heighten anxieties about the oligarchic possibilities inherent in technocracy. The pendulum began to swing toward dystopian discourses about technology and science. By the late 1960s, important new social movements criticized overreliance on technical experts and sought to reverse or reshape the direction of technological change. Most salient among these were environmentalism and the antiwar and antinuclear movements. Perhaps ironically, these movements soon claimed their "own" technical experts.

The cold war hence witnessed three overlapping and cumulative trends. First, between 1945 and 1970, technical experts' political purview within the

state expanded dramatically. Second, from the late 1960s into the 1980s, broad-based social movements effectively criticized expert power. Finally, from the 1970s into the present, credible expertise spread widely outside the state, opening technical decisions to adversarial politics.

COMPUTERS AND EXPERT POWER

In the post–World War II era, computer technology played a major role in strengthening the social power of scientific experts. This occurred throughout the developed world, and occasionally elsewhere as well, albeit differently in different places. To date, most of the historiography dealing with this phenomenon has focused on the United States, where it developed to perhaps its greatest extreme, for at least two main reasons. First, computers made mathematical analysis of scientific data far more efficient and far more powerful. They allowed scientists to apply numerical methods to a huge range of previously inaccessible domains. This process continues today, as computer modeling techniques spread into sciences such as ecology, genetics, and others that once relied chiefly on qualitative forms of analysis. Second, computers rapidly acquired a reputation for infallibility; they "could not make a mistake." By the late 1940s, popularizers and press accounts frequently termed the machines "giant brains."[44] The neurological imagery of cybernetics enhanced this association.[45] The machines thus developed an intimate symbolic connection with science, intelligence, and perfect rationality. The image of white-coated scientists standing before huge computers, waiting for answers as if worshipping at an altar, became a generally recognized trope. The sociotechnical characteristics of digital computing contributed to this effect, since until the mid-1960s, virtually all computers were large, expensive mainframes, accessible only through what some have called a "priesthood" of operators and programmers.[46]

This self-reinforcing conjunction of two forms of power—analytical and symbolic—conferred potency on computer-assisted forms of knowledge production and helped to legitimate scientific expertise in the United States. A particularly macabre example of this phenomenon was the cold-blooded production of nuclear war-fighting strategy by the RAND Corporation, a think tank founded by the U.S. Air Force in 1946. Though it quickly became clear that many millions of people would die in almost any imaginable nuclear exchange between the superpowers, RAND analysts cheerfully produced reams of computer-modeled strategic scenarios that defined "victory" as a greater percentage of survivors. Herman Kahn's books *On Thermonuclear War* (1960) and *Thinking about the Unthinkable* (1962) are perhaps the best examples of this twisted, computer-supported rationality.[47] Kahn inspired Stanley Kubrick's famous caricature, Dr. Strangelove, in his 1964 film.

RAND employed a motley collection of mathematicians, sociologists, economists, computer experts, physicists, and others, paying some of the highest

salaries then available for scientists and offering intellectual freedom and outstanding resources. RAND programmers developed the software for the SAGE air defense system, eventually spinning off a separate entity, the System Development Corporation (SDC), for that purpose. At the time, the SDC constituted the largest collection of computer programmers anywhere in the world; it was the first organization to gain expertise in programming large, highly reliable computer systems.[48] By the time of the Kennedy administration, RAND's expertise was frequently imported wholesale into policy planning.[49]

Computers played key roles in the design and production of American nuclear weapons. They supported scientific work, leading to powerful new weapons technologies. John von Neumann, the Hungarian émigré mathematician, first linked electronic digital computers with nuclear weapons design when he learned, in 1944, about the secret Electronic Numerical Integrator Analyzer and Computer (ENIAC) project. Von Neumann, affiliated with the Manhattan Project, knew that computation for the first fission bombs (the "atomic" bombs used at Hiroshima and Nagasaki) was being done with hand calculators and slow electromechanical punch card apparatus. He realized that the ENIAC would provide a much faster, more flexible way to carry out this work. Although the ENIAC was not completed until after the war had ended, by then von Neumann had become deeply involved in the project. He assisted in designing its successor, the Electronic Discrete Variable Automatic Computer (EDVAC), whose architecture became the basis of most computer designs from the mid-1940s until the early 1980s. At von Neumann's urging, the ENIAC's first use (in late 1945) was a mathematical simulation of a thermonuclear ("hydrogen") bomb explosion. By the mid-1950s, Los Alamos and other weapons laboratories had built copies of his pioneering Institute for Advanced Study computer. These machines and their successors became fundamental tools of nuclear weapons designers.

At the same time, computers helped to legitimate scientists as opinion leaders in political discourse. Von Neumann himself—an outspoken anticommunist and a military hawk—became an extremely important figure in post–World War II science and technology policy. Von Neumann also maintained key connections with RAND, where game theory famously became the basis for simulations of nuclear strategy. Thus, von Neumann personified the strong connection between computers, nuclear weapons, and scientific expertise in the early cold war. His personal fame and political influence contributed directly to public perception of this relationship.[50]

During the period of American combat involvement in the Vietnam War (1965–1974), computers helped to redefine "expertise" in the U.S. armed forces. Traditional armed forces defined expertise in relation to battlefield experience. But during the Kennedy and Johnson administrations, under the leadership of Secretary of Defense Robert McNamara, they came to seek quantitative understandings instead. McNamara's Defense Department placed a high priority

on collection of "data" on battlefield activity—such as the infamous body counts, maps of troop movements, and counts of vehicles destroyed—which it processed (with computers) into statistics that usually appeared to show progress toward winning the war, despite conflicts between these statistics and the frequently pessimistic reports of observers on the ground. Under McNamara, the Pentagon adopted RAND strategic concepts developed for nuclear confrontations in Europe; these turned out to be disastrously inappropriate for conflict with a highly motivated peasant guerilla army. In conjunction with new communications technologies, which permitted the White House to direct the bombing campaigns *in detail* from the other side of the planet, computers thus contributed significantly to the unrealistic strategy and performance evaluations that kept the United States mired in the war for so long.[51] As the antiwar movement peaked in the late 1960s, computer installations—by now firmly associated with military research and "establishment" power in the public consciousness—became frequent targets of sometimes violent protests. Protesters clearly registered both symbolic and real connections between nuclear weapons, computing, and the Vietnam War. In 1969, antiwar saboteurs destroyed computer equipment for nuclear missile guidance systems at a Sperry Corporation plant in Michigan. The following year, protesters firebombed a million-dollar computer center at Fresno State College.

The disastrous trajectory of the Vietnam War became one basis for changes in American public attitudes toward technological and scientific expertise that began to develop in the latter half of the 1960s. Associated as well with the youth counterculture and the environmental movement, this distrust reflected a sense of betrayal, as the dangerous downside of scientific/technological "advances" of the 1940s and 1950s became increasingly apparent. As the Vietnam War dragged on and its geopolitical counterpart, the cold war, entered its third decade with no end in sight, the equally endless quest for ever more powerful military technology came to seem more a problem than a solution for democracy and freedom. The terror associated with nuclear weapons, napalm, and other high-tech weaponry—together with fears about the environmental dangers of nuclear reactors, nuclear waste, long-lived pesticides, and the proposed supersonic transport, among others—began to override the confident sense of progress of the cold war's first two decades. In the United States, this growing challenge to the technological paths laid out by the cold war reached a first crescendo with the first celebration of Earth Day in April 1970.

Yet, as we noted above, these grassroots social movements soon understood that inchoate protest alone would rarely succeed politically against the voice of reason wielded by technical experts of the military, government, and industry. As they became more sophisticated, they began to claim their "own" expertise. Like the technocracy movement of the 1930s before them, they came to see expert knowledge as a powerful resource that they, too, could wield.

The antiwar and environmental movements also developed from within American scientific/technological elites. In 1968, a group of MIT faculty called on scientists to help "devise means for turning research applications away from the present emphasis on military technology toward the solution of pressing environmental and social problems," leading to the founding of the Union of Concerned Scientists the following year.[52] Other nongovernmental organizations such as the Club of Rome, an elite group of politically concerned industrialists and political leaders, helped to place environmental concerns on the agenda of national governments, particularly in the developed world. Based on computer models, the international best seller *The Limits to Growth* offered environmentalists an important rhetorical tool with its extremely pessimistic assessment of future dynamics in world resources, population, agriculture, and pollution.[53] Around the same time, climate scientists—basing their projections on computer simulations—began to warn of possibly catastrophic human-induced climate change within the foreseeable future.[54] Computer modeling has since become a fundamental tool for environmental scientists of all stripes.

Lay movements to debate technical issues on technical grounds marked the beginning of a new era in American politics. Expert knowledge—once seen as above the fray—now rejoined adversarial politics. Political actors engaged in contests of power and values would henceforth seek alignments and alliances with expert actors involved in contests over truth. Access not only to scientists but to their tools as well, became a key to technopolitical power.

Nuclear Expertise and Democracy

The history of opposition to nuclear technology illustrates the shift in how social movements conceptualized and used expertise over the course of the cold war. In the early years of the cold war, antinuclear opposition focused on weapons. The U.S. bombing of Hiroshima and Nagasaki triggered an initial wave of horror-induced protest against atomic bombs in the 1940s. But it was not until the mid- to late 1950s—with the development of the hydrogen bomb and the acceleration of nuclear weapons testing—that the disarmament movement gained momentum. Led by segments of the international scientific community and pacifist organizations, nuclear disarmament groups formed around the world. The earliest among these included Gensuikyo (Japan), Pugwash (a broadly international coalition that included Soviet scientists), SANE (United States), and the Campaign for Nuclear Disarmament (Britain). These groups were joined by others throughout Europe, Australia, and New Zealand.[55] Meanwhile, nonaligned nations in Asia and Africa opposed nuclear testing as a basic tenet of foreign policy, a theme of their unity, and a possible means to calm cold war tensions. At the 1955 Bandung conference of nonaligned nations, the Ceylonese representative suggested that nonaligned nations could become "mediators in the dispute between the giants of communism and anti-

communism which, if fought out to an end, will deluge the world in blood and leave the earth infected with atomic radiation."[56]

Particularly in the United States, the challenges posed by disarmament groups raised anticommunist hackles. Activist groups there were subject to FBI surveillance, and some of their leaders were hauled in for questioning by the House Un-American Activities Committee. Nevertheless, by the 1960s, the nuclear disarmament movement had acquired a discernible influence on world politics. It did not achieve its ultimate goal of abolishing nuclear weapons. But scholars Lawrence Wittner and Matthew Evangelista argue that it did play significant roles in shaping international treaties and government policies on both sides of the Iron Curtain.[57]

Early disarmament campaigns were more intent on critiquing government policy than on challenging the nature and function of expertise itself, perhaps because their leadership included internationally prominent scientists who tended to focus debates on the uses of knowledge rather than on the conditions of its production. As the movement's momentum began to wane in the late 1960s after the partial victory of the Nuclear Non-Proliferation Treaty, a new style of antinuclear activism took its place. This one targeted reactors rather than bombs, and challenged the nature and operation of expert power within the state.[58]

As the military atom became increasingly entrenched in the U.S., nuclear experts in the Atomic Energy Commission (AEC) turned their attention to civilian applications of nuclear technology. Pervasive, upbeat imagery promoted the infinite benefits of "our friend the atom," as did Eisenhower's enthusiastic "Atoms for Peace" initiative. Yet the successful development of commercial nuclear power was by no means foreordained. For one thing, utilities and manufacturers were reluctant to sink huge development costs into an unproven and uncertain technology with obvious risks. AEC experts had to create a demand for nuclear power, not only by investing in research but also by active lobbying among the public, Congress, and the utility industry.[59]

The special issues involved in reactor operation (the extremely long lifetime of radioactive materials, the potential risk of plant meltdown, plant decommissioning, and long-term waste storage, among others) required new kinds of expertise. The emergence of experts in areas such as reactor safety and utility economics led to a proliferation of experts outside the AEC. Scattered across a variety of agencies and research centers, these experts might proffer conflicting opinions. Techniques such as probabilistic risk analysis could not resolve these conflicts, and it became increasingly clear that expert assessments by themselves could not produce clear choices about reactor safety. In the United States at least, the legitimacy of expert power had been based on the assertion that expertise stood above—and apart from—politics. But the attempt to define reactor safety problems along narrowly technical and economic lines rapidly collapsed, as the social dimensions of issues such as waste

sites rose to the surface. Once politics stood revealed as integral to nuclear development, faith in experts as final, impartial arbiters was destroyed.[60] After the near catastrophe at Three Mile Island in 1979, the U.S. antinuclear movement saw major success. Purchasers have canceled all new reactor orders placed since 1979, although the United States has continued to derive 20 percent of its electricity from nuclear power plants constructed before that date.

Analysts explain the halt of nuclear development in the United States by a wide variety of factors. In part, increasingly visible disagreements among U.S. experts eroded public confidence. In response, the U.S. regulatory process became increasingly stringent, which in turn made licensing nuclear plants prohibitively expensive. The 1973 oil crisis together with the simultaneous rise of the environmental and antinuclear movements made nuclear power the center of partisan disputes over energy policy. And antinuclear activists knew how to build effective political coalitions at the local level, which enabled them to defeat nuclear power on a reactor-by-reactor basis.[61]

Antinuclear Politics in Germany and France: A Study in Contrast

The American antinuclear movement relied heavily on countering government claims with its "own" experts, who testified in local courts. By contrast, the even more successful antinuclear movement in Germany was profoundly antitechnocratic. In 1975, activists occupied a nuclear power plant construction site at Wyhl, Germany, for over a year, successfully preventing further work. This action was followed by mass protests at the Grohnde and Brokdorf sites in 1976–1977. These early successes helped galvanize a loose-knit coalition of environmentalists, feminists, antinuclear activists, and antitechnocrats, which entered 1980 election campaigns as the first Green Party. The Greens believed strongly in local knowledge and collective decision making (*Basisdemokratie*), rejecting any special role for technical expertise. Within a few years, the Greens gained a substantial minority presence in the West German parliament, sparking similar political movements across Europe. By 1989, the twilight of the cold war, Greens held about seven thousand elected local positions in West Germany.[62]

Nuclear power failed in Germany because the Green movement successfully focused the energies of environmentalists and antinuclear weapons protesters on this circumscribed, prominent target. This strategy gained important momentum from factors such as West Germany's position on the most likely front line of nuclear war in Europe and the highly unpopular U.S. move to introduce cruise and Pershing "theater" nuclear missiles there in 1981. At the same time, German regulatory traditions involved greater cooperation between expert analysts and interested parties than in the United States. By the

1970s, two emerging politico-legal principles marked a specifically German approach to questions of expertise. The cooperation principle held that decisions should be based "on all actors being informed to the same high degree," while creating environmental measures accepted by "all those involved or affected." The precautionary principle stated that "environmental risks and damage shall be avoided as far as possible from the very outset."[63] These principles were codified in German law in 1990. Many analysts have noted that the precautionary principle, in particular, shifts the burden of expert analysis from those who oppose to those who promote the introduction of new technology.[64]

In contrast to the United States and Germany, nuclear power in France enjoyed spectacular success. In 1971, after a protracted battle among engineers and managers within the nuclear industry, Electricité de France (EDF, the state-owned electric utility) decided to abandon the gas-graphite design developed by French engineers. France purchased a license to build light water reactors from Westinghouse, and utility engineers proceeded to alter and "Frenchify" this design. In 1974, responding to the oil crisis, the government proposed the Messmer plan, which called for the immediate construction of thirteen new nuclear reactors. These led to more, and by the late 1980s, France had fifty-four reactors producing up to 80 percent of its electricity needs—a higher percentage than any other nation in the world.[65]

Antinuclear protests in the 1970s were at least as vigorous in France as elsewhere. The protest movement started early there—by 1971, local groups had begun to oppose the construction of new sites. These groups joined up with the emerging Parisian ecology movement, and by late 1974, a loose coalition of antinuclear activists had begun to oppose the Messmer plan. This coalition was soon joined by the Confédération Française Démocratique du Travail (CFDT), a national labor union with a particularly strong presence among nuclear employees. The CFDT had strongly opposed the abandonment of gas-graphite reactors; its experts included nuclear engineers and scientists who produced massive reports to show why that design was technologically and economically more efficient. Defeated in that battle, they proceeded to develop extensive critiques of radiation protection and waste disposal practices. For the CFDT, the Messmer plan would only exacerbate the health and safety problems arising from weaknesses in these practices. By 1975, the CFDT had joined forces with antinuclear activists in order to call for a moratorium on nuclear development. As the movement gained momentum, critiques broadened to include the nature of decision making in the French state, which left no entry for outside experts or activists to participate in technology policy making. This critique helped turn the tide of popular opinion, which was becoming increasingly disgruntled with other aspects of French government policy, and by 1977, opinion polls showed that most French citizens opposed nuclear power.[66]

How can we explain the success of French nuclear power in light of such opposition? Ultimately, we must look to the ways in which technology and

politics were related in France. Within the state and its agencies, plenty of room existed for expert disagreement. Technology and politics were intertwined, as long as the politics in question operated within the state. Outside voices, however, had no place in state decision making; indeed, most technology policy decisions were made not by politicians but by the experts themselves. While regulatory processes might lead to alterations in reactor design or practice, they left no room to contest reactor development decisions themselves. EDF wooed public opinion back to nuclear energy site by site, with the promise of economic payoffs. Ironically, the utility was helped by developments within the antinuclear movement itself, which was hijacked by a small, extremist minority that espoused (and practiced) sabotage and increasingly violent demonstrations. Such techniques alienated public opinion. The erosion of popular support for the antinuclear movement left no more channels through which to oppose massive reactor development. CFDT experts and others had to content themselves with working within this system.[67]

Expertise in the Cold War

The two generations of activists and scholars who have investigated the hidden science and technology of weapons development and testing have produced the most recent legacy of nuclear protest movements. Their investigations have revealed countless abuses of expert power during the cold war. Western cold war ideology suggested that it was only in the Soviet Union and other Eastern Bloc nations that science and technology could be "distorted" through human experimentation, environmental devastation, and insufficient attention to the safety of technological installations. Certainly, recent evidence about nuclear development in the former Soviet Union suggests that the authoritarian regime and its lack of political accountability produced poorly functioning systems that devastated workers, residents, and the environment.[68] But studies show that the United States did not have an ideal track record either. Nuclear weapons manufacturing had serious consequences for both nuclear workers and the environment in the United States.[69] Experiments carried out by the AEC included releases of radioactive iodine into the atmosphere and injections of tracer doses of plutonium into medical patients, all conducted without the knowledge of the human subjects in question.[70] Such developments are only partly attributable to inadequate research protocols and innocent mistakes. The prevailing sense that any and all nuclear research was justifiable in the context of the cold war, together with the culture of secrecy that pervaded nuclear activities, helped make such abuses possible.

The reach of expert power during the cold war thus had multiple, often contradictory dimensions. The cold war often provided a mantle of secrecy under which to engage in otherwise socially unacceptable uses of technology. But public disappointment with the technological promises of the cold war

and disillusionment with the possibilities of expert power produced protest movements with international dimensions. These protests ultimately both reinforced and challenged the power of experts within the state. They reinforced it through their implicit agreement that political debates had to take place on technical grounds. At the same time, they undermined the authority of experts by pitting them against each other in public, political arenas. Against the backdrop of particular historical traditions and politico-legal infrastructures, these trends played out in different ways around the globe.

Nationalism, Colonialism, and the Reshaping of International Relationships

One of the major social and political dynamics of the cold war involved the reshaping of international relationships against the backdrop of changing nationalisms and decolonialization. This reshaping had important technopolitical dimensions. "Development" was the new order of the day. As expressed by Western political leaders and modernization theorists, development ideology linked scientific and technological progress with peace, democracy, and economic growth.[71] Meanwhile, the Soviet heavy-industrial model of progress differed little from that of the West on this account—except of course in its rejection of the free market. Henceforth, for poor and rich alike, technological achievement would appear to replace empire as an indicator of geopolitical power.

As a new symbol of nationalism, nuclear systems were among the quintessential enactments of this shift. With an ambivalent eye on the United States and increasing concerns about decolonization, British and French leaders in particular began to argue that the basis of international power was no longer empire, but nuclear bombs—and their nations had better make the switch before it was too late. Atom bombs would even prevent imperial states from themselves becoming reduced to colonized subjects. Witness Churchill's chief scientific advisor in 1951: "If we have to rely entirely on the United States army for this vital weapon, we shall sink to the rank of a second-class nation, only permitted to supply auxiliary troops, like the native levies who were allowed small arms but no artillery."[72] Or French parliamentary deputy Félix Gaillard, the same year: "those nations which [do] not follow a clear path of atomic development [will] be, 25 years hence, as backward relative to the nuclear nations of that time as the primitive peoples of Africa [are] to the industrialized nations of today."[73] Even as it fueled the world's most modern industry, Africa remained the eternal metonym for backwardness. Such discourse functioned by mapping two proclamations of geopolitical rupture onto each other: nuclear equals (former) colonizer; non-nuclear equals colonized (or formerly so). In practice, however, nuclear sociotechnical systems depended upon,

reinforced, and reformulated colonial relationships, particularly in the domains of uranium mining and weapons testing.

If colonialism was deeply implicated in the development of nuclear systems, the same was not true for computers. Throughout most of the cold war, colonial and postcolonial relationships were notable primarily by their absence in computer technopolitics. Instead, nationalism provided the dominant theme. In the first two decades of the cold war, computer nationalism was partly fostered by military security concerns, as early advanced computers served primarily for code breaking and nuclear weapons design. U.S. export restrictions on advanced computers led to national sponsorship of computer industry development in Great Britain and France, linked directly to the independent nuclear capabilities of those nations. In the early 1960s, the association of computers with cold war military power began to sink beneath the level of public awareness, as the civilian computer industry boomed. By the early 1980s, computer manufacture had become transregionally networked, with Japanese computer manufacturers and "Asian Tiger" component suppliers and assembly plants playing central roles. These developments spurred new forms of computer nationalism, particularly as U.S. manufacturers began to feel threatened by Japanese industrial strength.

In the first three decades of the cold war, both the relative absence of colonial and postcolonial dynamics from computer development and the particular form they took in nuclear development were a complex product of technopolitics and geopolitics. Like many military technologies of the era, both systems depended upon many kinds of highly specialized expertise. Their production also required advanced manufacturing systems. By the mid-1970s, integrated circuits had to be produced in special "clean rooms" by scrubbed-down technicians wearing bodysuits; even microscopic dust particles could ruin silicon wafers. Similarly, nuclear weapons depended on the ability to machine and handle extremely dangerous materials, including conventional explosives as well as uranium and plutonium. Nuclear power demanded complex, redundant safety systems as well. Such requirements marked the generalized concentration of technical expertise and infrastructure in the developed world.

These conditions rarely existed in either colonial territories or postcolonial nations. For most of the latter, the manufacture of goods and the extraction of raw materials remained the major "development" path. In the case of nuclear systems, this meant that mineral extraction and the provision of "wastelands" for weapons testing dominated the relationships between nuclear powers and colonial or postcolonial territories. In the case of computer systems, it meant that colonial and postcolonial territories—particularly in Africa—were by and large excluded from the first few decades of technological development.

Nevertheless, both nuclear and computer systems were central to the ideologies and practices of scientific and corporate international relations. In practice, weapons and reactors were ultimately the products of internationally

produced knowledge. No nation actually built nuclear technologies based solely on knowledge produced by its own experts. The key issue, therefore, concerned which nations could legitimately have access to what kinds of knowledge. Meanwhile, computers played a major, but largely behind-the-scenes, role in creating the globally networked multinational industries that emerged in the 1970s—although the "global" nature of the network was partial at best, excluding much of Africa. Operating any organization on a transregional scale requires a highly organized information system; combined with global telecommunications systems and key organizational innovations, computers offered the possibility of real-time control of multinational, networked organizations. By the mid-1970s, the latter represented an indirect but powerful challenge to the superpower governments. By parsing their manufacturing and management operations among many national locations, multinational corporations could not only reduce labor costs but also engage in what analysts call "regulatory arbitrage," choosing the most advantageous regulatory regime. As Manuel Castells and others have shown, the "informational economy" that emerged in the 1970s vastly amplified its power and reach by means of new, computer-based information technology. Not coincidentally, this technology was mainly available to the former colonial powers, the United States, and (later) to the Soviet Union. The different ways in which nationalism, colonialism, and international relations interacted within nuclear systems and computer systems represent important, parallel (if connected) trends in the role of technology during the cold war.

Nuclear Development in Colonial and Postcolonial Context

Nuclear technologies embodied national identities by signifying progress, modernity, independence, or renewal. Nuclear nationalisms typically emphasized how scientists and engineers had worked in isolation to produce their nations' nuclear capabilities and stressed that national technological systems formed the basis for political and economic strength. The heroes of these stories— often the only visible actors—were bombs, reactors, scientists, and engineers. Nuclear nationalisms, in other words, obscured the colonial relationships necessary to their existence.

Colonial territories had been sources of radioactive materials even before World War II. Most of the world's radium had come from a single mine in the Belgian Congo. This mine also supplied most of the uranium for the Manhattan Project, and continued to produce uranium for the United States and Britain after the war. Other nations also needed colonial territories for their own nuclear development. France could pursue an independent nuclear program because it had access to uranium not just on metropolitan soil but also in its

African colonies. Britain's colonial ties to uranium-supplying regions in Africa and Australia helped maintain nuclear relations with the United States after the war. European use of African uranium continued well after decolonization. The French program, for example, used uranium from Madagascar in the 1950s and 1960s, from Gabon starting in the 1960s, and from Niger starting in the 1970s. Throughout the cold war, South Africa derived uranium from the tailings of gold mines exploited under apartheid, and sold it to the United States and Britain. Beginning in the late 1960s, the Rössing uranium mine was one of the centerpieces in South Africa's colonial occupation of Namibia. But colonial conditions existed outside of Africa too—particularly in East German mines, where the Soviet nuclear program used prison labor to extract and refine uranium ore. Finally, internal colonial dynamics also played an important role in the acquisition of uranium. Rich deposits occurred on Native American lands in the United States, aboriginal lands in Australia, and tribal lands in India.[74]

Uranium mines were among the least visible elements of the nuclear system. This invisibility had several causes: the need to keep ore reserves secret, particularly in the early cold war; the remote locations of mines; and the fact that mining uranium used many of the same technologies as other mining industries. At the other end of the fuel cycle, the opposite was true. Weapons testing was the most visible element of the nuclear system. Only a successful test could officially bring a nation into the nuclear weapons "club." Testing was thus both a rite of passage and a strong political statement. Yet testing shared one important feature with mining: it was conducted primarily in colonized, recently decolonized, or tribal spaces. The United States conducted its earliest tests in the Marshall Islands, infamously displacing Marshallese from their homelands. In the early 1950s, the testing program moved to the Nevada desert, in territories used by Indians for hunting and grazing. France exploded its first bomb in Algeria, and conducted subsequent tests in the Moruroa atoll in French Polynesia. Great Britain tested bombs in Australian Aboriginal territories. The Soviet Union tested on tribal lands in the Arctic, and China on nomadic lands near the Soviet border.[75]

Colonized, recently decolonized, and tribal lands were not the only ones subject to nuclear testing, nor were they the only sources of uranium. Yet such spaces were, without question, disproportionately represented at these two extremes of the nuclear fuel cycle. What explains their predominance? More than bad geological or geographical luck was at play. Prospectors favored land they perceived as empty, uninhabited, or underutilized; so did officials searching for propitious nuclear test sites. Places like the Nevada desert or the Arctic tundra seemed like wastelands, their inhabitants invisible. As Valerie Kuletz argues, "environmental science discourse often supports . . . discourse about desert lands as barren wastelands by organizing bioregions within hierarchies

of value according to production capacity." Similar hierarchies place indigenous people and nomads "at the bottom of the ladder of economic productivity."[76]

Colonial and postcolonial territories were thus more susceptible to being seen either as barren, or natural resources ripe for exploitation—a perspective that in fact had provided much of the original rationale for European imperialism and American expansionism. In cold war developmentalist discourse, using such places for nuclear purposes would valorize them by giving them a place in the grand march of progress led by nuclear technology. Valorization could go hand in hand with nationalism. This pairing was especially striking in the hands of the French. President Charles de Gaulle prefaced his announcement of the Moruroa test site by thanking the Polynesians for having rallied to the cause of the Free French in World War II: "I have not forgotten this, and it is one of the reasons why I chose Polynesia for the installation of this site."[77] The test site was described as a gift of gratitude, one that would bring ample economic fallout, help Polynesia modernize, and give it an important role in upholding the grandeur of France.

The world's largest nuclear powers thus *needed* colonial resources and spaces. But framing this relationship in terms of dependence would have undermined the symbolic value of nuclear achievement; hence the language and practice of "development." Mines of all kinds were supposedly conducive to development by encouraging local economic activity, imparting industrial skills and work habits, and producing exportable commodities. Mining was said to be especially important for newly independent nations by giving them a base upon which to build their economies. National nuclear programs drew on this international developmentalist rhetoric, particularly when they set up uranium mines in Africa. By the 1980s, when economic indicators began to show that near-exclusive reliance on mining only exacerbated poverty by making southern economies too vulnerable to the vagaries of markets over which they had no control, nuclear programs had by and large dropped out of the uranium mining business. In their place came multinational corporations.

Corporate Actors and Government Secrets

Until the 1960s, government-driven programs had dominated uranium mining, which was directed primarily at supplying nuclear weapons. The 1960s witnessed a glut in uranium supplies. Fuel needs for the U.S. arsenal (by far the largest) were met, but reactors had not yet attained commercial viability. In the mid-1970s, as nuclear power commercialized and spread, the demand for uranium increased again. This time, multinational corporations (often in partnership with oil companies) led mining efforts. The rhetoric of development served corporations well: they styled their mines as endeavors to encourage economic and technical progress in the third world.

One set of forces that defined the international shape of the nuclear industry thus involved colonial relationships and their transformations under the new rubric of developmentalism. Another, intersecting set of forces involved the reworking of scientific internationalism under cold war conditions. Before World War II, nuclear physicists and chemists had been prominent practitioners of scientific internationalism, and many chafed at the secrecy that pervaded nuclear programs after the war. Secrecy meant isolation: at least in principle, any country wishing to develop an atomic bomb had to do so on its own, using indigenous knowledge. France, China, and later India elevated this alleged isolation to a matter of prestige, proudly proclaiming the indigeneity of their bombs and reactors. But no nation, not even the United States, developed either military or civilian nuclear systems completely on its own. Nations did not just rely on colonial holdings for raw materials—they also relied on each other for knowledge. The Manhattan Project drew heavily on the work of émigré scientists and had branches in Canada and Britain. Britain, in turn, drew on the experience provided by this wartime collaboration to develop its bombs—as did French scientists, who also benefited from later, veiled discussions with British colleagues. Israel learned from France; China, from the Soviet Union; and so on. Claiming that bombs were indigenous, therefore, usually involved obscuring the international exchanges—colonial or otherwise—needed to produce them.

These exchanges also complicated the determination of what constituted a "nuclear secret." Basic scientific knowledge concerning fission and fusion was widely available. Bomb design fell more clearly into the domain of privileged information, though as the cold war progressed it too became less of a mystery. The same applied to the techniques required to produce various bomb components (such as isotope separation to make weapons-grade fuel). By the 1960s, the most technologically difficult aspects of weapons production lay not in the basic knowledge necessary to make bombs, but in engineering and managing the gigantic systems required to build them. The most politically difficult aspects involved controlling the flow of information, materials, and expertise—not just through international arms control treaties but also through sanctions and export controls. Countries such as India, whose weapons development was condemned by the "international community" (in this context, a phrase that signified the members of the United Nations Security Council) in turn decried this condemnation as neocolonial.

While military nuclear knowledge retained an aura of secrecy throughout the cold war (and beyond), access to civilian nuclear knowledge opened up beginning with the 1955 Geneva Conference for the peaceful applications of atomic energy. This event was meant to revive internationalism in the nuclear arena. In fact, the conference involved a curious blend of nationalism and internationalism. Each country mounted its own booth, displaying scale models of its nuclear achievements to date. Papers imparted serious scientific and

engineering knowledge framed in terms of national achievements. At the same time, the conference generated tremendous nuclear utopianism: thanks to unprecedented international cooperation, nuclear technology would soon solve the planet's energy problems and lead to world peace. Electricity would be "too cheap to meter." Rich nations would help poor ones develop nuclear power plants, and everyone would be better-off in the process.

Created in 1957, the International Atomic Energy Agency (IAEA) was an outgrowth of the first Geneva Conference and Eisenhower's "Atoms for Peace" program. The agency had two aims: safeguarding the world from the military atom, all the while fostering the spread of "peaceful" nuclear technology. The first aim was to act as a counterbalance to the insanity of the superpower arms race. When viewed from nations that would become nuclear pariahs—in particular, South Africa, Iran, and Iraq—this aim appeared to perpetuate global inequalities by attempting to ensure that only a few very powerful nations would have access to the most modern military hardware and the techniques of apocalypse. The second aim was considerably less contested. It combined development ideologies instantiated in institutions like the World Bank, the belief that nuclear power held the key to all progress, and long traditions of scientific internationalism in nuclear research. The IAEA appeared to hold that there was no nation, however poor, that could not benefit from at least some nuclear technology or science. In this realm, the agency acted as the main structure within which international nuclear exchange might occur. This exchange could be "purely" scientific. It could also serve as a precursor to commercial relations. And there were more and more of these as time went on: the United States, Canada, and France were particularly eager to export their reactor technologies.[78]

Nuclear technopolitics thus perpetuated and transformed the global relations of dominance inherited from colonialism, both through its material (mining and testing) and political (international organizations and treaties) practices. At the same time, the rationale for these relations changed in important ways. The colonial "civilizing mission" had been transmuted into the competing development ideologies of the cold war superpowers, including the People's Republic of China. Together with "global security" (to prevent nuclear apocalypse), it now provided the order of the day. Imbricated with nuclear systems (among others), these priorities provided one of the technopolitical infrastructures for the redistribution of global alliances of the cold war (East, West, and nonaligned).

COMPUTERS AND TECHNOLOGICAL NATIONALISM

Computers became the core of another transregional—some would say global—technopolitical infrastructure. Since the early 1990s, this infrastructure has become visible as the global Internet and World Wide Web. But the

groundwork for the Internet was laid during the cold war, as the spread of electronic computers created a new standard: digital formats for data, information, and communication. These could be copied and transmitted far more easily and less expensively than under previous technological regimes, but they required vast investments in equipment, training, and conversion from older analog formats. The possibility of linking computers through networks emerged in the 1970s. Computers, networks, and other techniques for digital data processing played a major role in the rise of multinational corporations during the 1970s, helping to create what Manuel Castells has called a global economy capable of operating in real time on a planetary scale.[79]

Dimly aware of the digital juggernaut gathering momentum in America, national governments throughout the world responded in many ways. Here we focus primarily on developments outside the United States. For those who view the current internationalization of the computer industry as inevitable, what may prove most striking in these histories is how many nations developed their own indigenous computer industries. These national drives were often connected to the early military significance of computers, as well as to impulses of technological nationalism similar to the ones driving nuclear development. Technological nationalism generally failed in the computer field, largely because a single company (IBM) came to dominate the world market in the mid-1960s, introducing a powerful strategy of standardization and component compatibility in which most other companies were forced to participate in order to survive. Yet in the 1950s, before IBM had consolidated its grip and while computers were still a new, unformed technology, many nations explored their own paths into digital information technology. Even after IBM systems became the world standard, national governments sometimes sought to resist its technological regime through projects to build indigenous computer production. The following brief discussions illustrate how some of these efforts were shaped by their particular technopolitical contexts.

In the 1950s, Great Britain had a vigorous indigenous computer industry, responsible for virtually every computer installation in England until 1960. In 1945, Great Britain possessed the world's most advanced computers, built in secret for its World War II code-breaking operations. That these machines surpassed their American equivalents was first confirmed in the 1970s, when the British military declassified its documents on the Colossus I computer.[80] After World War II, the Ferranti Corporation became the first to market programmable digital computers, primarily to the British nuclear weapons program.

These and other military-sponsored projects accounted for the bulk of British computer sales. In the United States in 1956, IBM and Sperry Rand contracted to build supercomputers for atomic weapons research and code breaking. Seeking to compete, the British government funded the Muse/Atlas supercomputer at Manchester University. According to Kenneth Flamm, "when completed in 1962, Atlas was among the most powerful scientific computers

in the world."[81] In the mid-1960s, Britain's National Physical Laboratory developed one of the world's first computer networks, a direct ancestor of the Internet. Yet around the same time, the fragmented British computer industry was collapsing, overwhelmed by the U.S.-based IBM. Flamm traces this decline to lower levels of integration between military research and commercial application.

A somewhat similar pattern developed in France. Despite a late entry into the new field, the French-owned Machines Bull developed commercially successful computers in the early 1960s. Apparently without government prodding or support, the company decided independently to compete with the U.S. and British military supercomputer projects. Lacking the military subsidies of these counterparts, the Bull project failed, and the French CEA (atomic energy commission) purchased its supercomputer from IBM. Disastrous financial consequences for Bull ensued, and the firm was purchased by General Electric—leaving France with no major indigenous computer producer.

In 1966, the CEA again sought to purchase an American supercomputer for its nuclear weapons program. This time the U.S. government—which opposed an independent French nuclear arsenal—refused to license the export. Although the CEA nonetheless completed its weapons calculations, secretly using an identical supercomputer already installed at a civilian firm, the incident caused a public scandal. French independence, self-determination, and national identity, already linked to nuclear weapons and nuclear power, were again at stake. In part as a result of this crisis, the government initiated a series of programs known as the "Plan Calcul" (1967–1980). The plan sponsored a new "national champion" firm, the Compagnie Internationale pour l'Informatique (CII). Despite the CII's mediocre technological and market performance, guaranteed government procurement programs kept the firm alive through the 1970s. Clearly, successive French governments found an indigenous computer industry vital to French national interests. In 1978, President Valéry Giscard-d'Estaing commissioned an influential report on the "informatization of society."[82] Characterizing "telematics"—the combination of telecommunications and information technology—as the wave of the future, the report argued that France had to seize the initiative or fall by the wayside in the coming era of computing for the masses.

In response, France launched a major, prescient technological initiative, a videotex system known as Télétel. Using the newly modernized national telephone network, Télétel offered two-way text transmission using small terminals known as "Minitels." The French Postes, télégraphes et téléphones (PTT) gave away more than six million Minitel terminals between 1980 and 1992, supplying free access to a national telephone directory and other databases. With for-pay chat services and online pornography, the system saw a tremendous boom in popularity during the 1980s. The system ultimately foundered in the mid-1990s with the advent of the more flexible Internet. But Télétel

remains the first example of a computer network as a mass communication service—and a potent symbol of French technological prowess.[83]

More than any other nation, Japan explicitly connected computers with national identity. U.S. cold war policy promoted a strong Japan as an Asian buffer against Soviet expansionism and Chinese communism. The postwar Japanese constitution radically limited defense spending, while U.S. forces provided protection in exchange for military bases in the region. Japanese industry concentrated on high-technology manufacturing in areas such as automobiles and electronics. By 1966, the Japanese Ministry of International Trade and Industry (MITI) "identified the computer industry . . . as the single most important element in the future economic growth of Japan."[84] Stringent import controls and a strategy focused on component manufacture produced, by the late 1970s, a Japanese computer industry capable of going head-to-head with IBM—albeit sometimes through devious or even patently illegal means.[85]

Thus, the 1960s "economic miracle" of "Japan, Inc." began as a deliberate U.S. geopolitical goal. But as tensions mounted during the Carter-Reagan cold war, U.S. policy makers began to see Japanese technological prowess as a national security threat. Computerization lay at the heart of American military strategy. In 1981, MITI announced the Fifth Generation Computer Initiative. Budgeted at $855 million over ten years, the plan sought to leapfrog U.S. technology. The possibility that another nation might control supplies of vital components, or even come to dominate computer manufacture, was intolerable to the Reagan administration. It responded in 1983 with a $600 million Strategic Computing Initiative (SCI), organized by the Defense Advanced Research Projects Agency (DARPA). Tellingly, where the announced goals of the MITI program focused on peaceful uses, Strategic Computing planned military applications for the electronic battlefield of the future. The renewed military investment in computer research aroused widespread controversy in the United States. Though both the MITI and the DARPA plans ultimately faltered, each succeeded in linking computers to the very different national identities of their respective sponsors.

Perhaps the most vigorous independent effort to deploy computers as technopolitics—and the most dramatic failures—occurred in the Soviet Union and its satellites. Centrally planned economies seemed to cry out for computer-powered information management. Potentially, computers could open a data window through which planning bodies could view production, distribution, and consumption figures at all levels, from whole nations to factories and local distributors. Indeed, by the late 1960s, Soviet central planning bodies sought to introduce computer-based management and control systems into heavy industry almost by force. Interestingly, these attempts foundered in the 1970s for social reasons—especially massive built-in disincentives for managers on the ground. Factory directors realized that while the new systems might improve efficiency in the long run, during a long, complex introduction and adjustment

period they would actually reduce productivity. In addition, these managers saw that computerization would render factory operations more transparent and accountable to central planning agencies. Local managers rightly feared that such transparency might strip them of the power to hoard scarce supplies and labor—a power critical to their success in the Soviet system. Thus, the overall sociotechnical system's contradictory goals effectively prevented adoption of an ostensibly more efficient information technology.[86]

Brazil, unlike most Latin American countries, consistently invested relatively large sums in science, and particularly in physics, during the cold war. With the advent of transistors and other computer-related solid-state technologies in the 1950s, a few Brazilian physicists decided to concentrate on solid-state physics, expressly for the purpose of developing scientific computers of their own. A late 1950s collaboration with Israeli scientists led to a joint project to build a mainframe computer in the 1960s. By then the Brazilian Navy had begun an initiative to develop indigenous computer-building capacity for national economic development. Major domestic political changes during the 1960s (most notably the military coup of 1964) shattered near-term hopes for an independent indigenous computer industry, but this project had by then become important to a substantial group of "pragmatic antidependency guerillas" who continued to push it forward.

In 1978, the military government adopted a "market reservation" policy stringently restricting imports of minicomputers and microcomputers. (Mainframe computers were recognized as beyond the capability of indigenous manufacturers.) The military viewed an independent information technology industry as critical to both Brazilian and Latin American security. By limiting foreign competition, the market reserve approach had worked in other sectors to create indigenous industries. Brazilian nationalism made these policies widely popular; they were seen as counterhegemonic struggles against the cultural and economic dominance of the United States, and the democratic governments elected after 1984 therefore continued the policies.[87]

Market reservation also, however, produced high costs for users and created a black market in smuggled computers and computer parts. Perhaps most significant, these policies provoked a major confrontation with the United States in 1986–1987, at the behest first of IBM and later of Microsoft. After President Reagan threatened $100 million in trade sanctions, Brazilian president Sarney softened the market reserve policy substantially. Overall, the policy led to mixed success, bolstering an indigenous industry, but also generating high prices and a black market in smuggled IBM machines. In the end, Brazil's explicitly technopolitical strategy failed to overcome the dominance of the global, United States-led marketplace.[88]

In the case of South Africa, nuclear ambitions connected closely with the fate of the indigenous computer industry. Isolated by the international community due to its racist system of apartheid, South Africa adopted policies

intended to preserve its regime at all costs—"total war and total strategy."[89] The government launched nuclear weapons research and production around 1974. International sanctions intended to thwart these policies included export restrictions not only on military matériel, but also on "dual-use" technologies. "Dual-use" restrictions embargoed the sale of computers, computer components, and some software (such as encryption systems) to South African police and military forces.

Using front organizations, third-party transfers, and other techniques, the government evaded most embargoes. Government users pirated key software; in the early 1990s, the Atomic Energy Corporation spent more than $1 million to buy licenses for software it was already using.[90] Military users sought supercomputers for such purposes as nuclear weapons design and battle simulation. But smaller mainframes, minicomputers, and even the desktop computers just reaching the market in the early 1980s also played significant roles in the apartheid state, a dark form of technopolitics indeed. Apartheid relied on a complex, internally contradictory classification system determining every individual's legal status as white, colored, black, and so forth. Passbooks up to ninety-five pages long recorded every legal aspect of nonwhite citizens' lives, and could be demanded by police or other officials at any time. Computer systems helped Pretoria's Department of Plural Relations and its regional Bantu Administration Boards centralize this information.[91] During the 1980s, activists in the United States and the Netherlands documented numerous ways that South African police deployed computers, from tracking individuals to tactical police communications.[92] However, mid-1980s plans for comprehensive computerization were only partially fulfilled.

Ironically, computer embargoes forced South Africa to build strong, independent capability in hardware manufacture and software design.[93] For example, the South African information technology company Dimension Data traces its success to this situation. Founded in 1983, not long after the embargoes began to take effect, DiData went on to become an $11 billion company, dominating the networking industry in South Africa while building operations in more than thirty-five countries on five continents.[94] Infoplan, a quasi-governmental corporation tightly linked to the South African military, helped to manage the regime's computer stockpile.[95] Today it remains the information technology facility of the defense forces.

In the twilight of the cold war, computers played a part in apartheid's demise. During the mid-1980s, with the help of Dutch and British activists, the African National Congress (ANC) developed an encrypted communications network, known as "Vula," employing personal computers, modems, tape recorders, and pagers (before the Internet era). By 1989, Nelson Mandela himself used Vula (through intermediaries) to communicate with other ANC leaders from his prison cell. A Vula founder notes that until 1985, a poor communication system severely hampered the ANC's effectiveness both as an army

and as a political organization; Vula dramatically improved communications.[96] A few years later, apartheid was in its death throes.

South Africa, a white-dominated nation tightly integrated into the world economy through U.S. and European multinationals, was the exception rather than the rule in Africa. Very few former African colonies have significant computer capacity even today. In the technopolitics of information systems, the legacy of colonialism for Africa was not *obscured inclusion* in global systems (as in the case of nuclear development) but rather *counterintegration*. Until the 1980s, when personal computers became a commodity product that could be exported with relative ease, most computer technology relied on other infrastructure not readily available outside the developed world. This infrastructure included not only complex, advanced hardware but more important the social infrastructure of trained programmers and computer engineers. The developed world's extractive relationship with Africa created only the bare skeleton of a modern communication and information system, a bitter inheritance with which the continent now struggles.

As the foregoing examples demonstrate, throughout the cold war, technological nationalism motivated numerous attempts around the world to build indigenous computer industries. Though most ultimately collapsed in the face of the American juggernaut, some—such as the French Minitel—succeeded at least briefly. Even when they failed, however, they laid groundwork for the burgeoning infrastructure of globalization, creating digital information environments and new expectations. The fragmented, uneven distribution of today's global computer-based information infrastructure thus reflects, darkly, the history of colonialism and cold war technopolitics.

Conclusion

The end of the cold war has led political leaders and the mass media to talk about "new world orders," sometimes signifying the decline of superpower tensions, other times that murky process reified as "globalization." Assumptions that technological progress is unilinear and exogenous undergird this rhetoric, shaping claims that range from the necessity of antiballistic missile defense to the benefits of global connectivity. New times, we are told, call for new technologies.

Bringing the themes and scholarship we have discussed here into the classroom can help teach our students that neither the times nor the technologies are as new as they might think. Today's technopolitical order has direct roots in the cold war. Neither the proliferation of weapons of mass destruction, nor the varied international responses to this proliferation can be understood separately from this history. Weapons are not merely the tools of political leaders, and technological systems more generally have far-flung political and cultural dimensions. "Globalization" is not a single, uniform, technology-driven process;

it means different things everywhere, its technologies have long histories, and their development has social, political, and cultural dimensions and consequences. Exposing students to the relationships between technological and political change and their complex cold war history can teach them to unpack public rhetoric and ask important questions about the social processes that shape their lives.

At the same time, post–cold war developments have made it increasingly urgent for scholars to examine technopolitics in transregional perspective. As our survey makes clear, huge geographical gaps remain in our understanding of these phenomena. The analytic gaps are also large. How can we move beyond comparative analysis to understand how technopolitics connected or disconnected different regions of the globe? How can we place explorations of the microprocesses of technological change in a transregional framework? Many of these issues are too large for scholars working independently; tackling them may require not just new conceptual structures but also new, collaborative methods of research. We hope this chapter will help stimulate such endeavors.

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