Was the Nuclear Arms Race Deterministic?

by

Alex Roland

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An arms race, like a duel, allows both sides to choose their weapons. One of the most remarkable characteristics of the Cold War arms race between the Soviet Union and the United States was that the two sides chose nearly identical weapons—and thousands of them, indeed, tens of thousands. Their combined arsenals exceeded seventy thousand nuclear warheads at their peak, with first one side and then the other enjoying numerical superiority. On balance, their nuclear capabilities were **proportional**. To place these bombs on selected enemy targets, both sides maintained thousands of delivery systems. The Soviet and American arsenals were not only proportional, they were **symmetrical**. To carry their very similar warheads, each side maintained bombers, land-based inter-continental ballistic missiles (ICBMs), and submarine-launched ballistic missiles (SLBMs) staged on nuclear submarines. The two sides also pursued similar programs in missile defense, cruise missiles, and intermediate-range (or "theater") ballistic missiles. In the later stages of the Cold War, the two sides codified the **proportionality** and **symmetricality** of their strategic arms in a series of bilateral treaties. It was President Ronald Reagan's insistence on pursuing a space-based missile defense that threatened the "balance of terror" in the two arsenals and contributed to the unraveling of the Soviet Union.[1]

[1] Albert Wohlstetter, "The Delicate Balance of Terror," RAND P-1472 (Santa Monica, CA: RAND Corporation, 1958).

In addition to making the superpower arsenals look alike, the instruments of strategic nuclear war also seemed to make the superpowers themselves look alike. Was the arms race deterministic in the shaping of society? Did these arsenals call forth the national-security state, what some have called the military-industrial complex, and what David Edgerton has recently called the "warfare state"?[2] Were the politics and economics of the Cold War driven by the nuclear arms race? Did the superpowers suspend above the world a sword of Damocles that cast a shadow of war over all humankind on Earth?[3] Was the mushroom cloud an icon of technological determinism, of the power of weapons to set policy?[4]

The proportionality and symmetricality of the nuclear arsenals suggests that the superpowers did not choose their weapons. Rather, the weapons chose themselves. The policy that came to dominate the Cold War—MAD, or Mutual Assured Destruction—suggests that the weapons were not tailored to strategy but rather the strategy was shaped to suit the weapons. In both cases, agency appeared to reside not in Hephaestus but in his forge.

Is this appearance of determinism real or illusory? If real, what was deterministic, the technology or the duel? Are all arms races deterministic? Are all duels deterministic? Does the determinism shape both the nature of the weapons and the nature of the contest? Is it only wars and weapons that are deterministic or are all competitions between material forces—say in markets or athletics—similarly circumscribed by technology?

The overwhelming proportionality and symmetricality of the two strategic arsenals in the Cold War trumped the many differences between them. The Soviet Union was first to develop a working intercontinental ballistic missile, the R-7 Sapwood, which first flew in May 1957. The same rocket launched *Sputnik* in October of that year. Thereafter the Soviets modified that rocket incrementally over the course of the Cold War, using it after 1968 exclusively as a space launch vehicle. The United States, in contrast, came late to the game and developed more elegant and generally less powerful missiles. Its first successful ICBM, the Atlas, inaugurated in 1959, was so light and fragile that it could not support its own weight on the launch pad until it was filled with fuel.

The United States innovated far more rapidly than the Soviet Union, but the Soviets managed to imitate most American developments in time. Americans favored bombers and submarines, while the Soviets favored land-based missiles, but both sides competed in all three realms. In 1987, Lawrence Martin counted 11,466 strategic warheads on 1,937 delivery vehicles in the American arsenal, compared with 11,241 warheads on 2,801 vehicles for the Soviets.[5]

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2 David Edgerton, *The Warfare State: Britain, 1920-1970* (Cambridge: Cambridge University Press, 2006).

3 Michael Sherry, *In the Shadow of War: The United States since the 1930s* (New Haven: Yale University Press, 1995).

4 Quincy Wright suggested that technology has been the main driver of war in the last half millennium in *A Study o f War* (Chicago: University of Chicago Press, 1965). A.J.P. Taylor demonstrated how military technologies could pipe the tune in *War by Timetable: How the First World War Began* (London: Macdonald & Co., 1969).

5 Lawrence Martin, *The Changing Face of Nuclear Warfare* (New York: Harper & Row, 1983)

In its symmetry and scale, the Cold War nuclear arms race resembled the other great arms race of the twentieth century, the Anglo-German naval race preceding World War I. Germany chose the scale of the race by challenging Britain's command of the sea and forcing the Royal Navy both to abandon its Two-Power strategy (to maintain a fleet larger than the next two powers combined) and to recall ships from its world-wide commitments to beef up the Home Fleet in the North Sea. Britain drove the symmetry by introducing the all-big-gun battleship with the launching of HMS *Dreadnought* in 1905. Pre-*Dreadnought* battleships receded into obsolescence as Britain, Germany, and other would-be naval powers accelerated building programs to produce the new style of capital ship.[6]

Like the Cold War nuclear arms race, the naval standoff between Britain and Germany proved to be a war of deterrence, in this case between what American naval theorist Alfred Thayer Mahan called "fleets in being." The British Home Fleet and the German High Seas Fleet met only once in World War I, at the inconclusive Battle of Jutland in 1915.[7] Thereafter the German fleet stayed home but tied down British naval resources with the threat of sallying forth once more. The vast and symmetrical naval arsenals of the two powers cooled their guns for the duration of the war. The more telling naval war between Britain and Germany was to revolve around a comparatively small number of German submarines and an asymmetrical campaign by the allied powers to meet this unexpected threat.

What made the arms races between Britain and Germany before World War I and the United States and the Soviet Union in the Cold War symmetrical and proportional? In choosing weapons, why did the two sides arm themselves with the same instruments in the same quantities? Perhaps the dynamics of great-power war in the twentieth century bred this kind of parallelism. Perhaps modern war promotes contests of industrial production. Perhaps such arms races reveal nothing more than a lack of imagination, a kind of copycat impulse that drives one state to match the arsenal of a potential competitor. Or maybe arms races are inherently deterministic. Perhaps potential combatants gravitate to a norm of "weapons symmetry," and the very symmetricality dictates the proportionality.[8] Having chosen the same weapons as the enemy, one is naturally drawn to match or exceed the enemy's numbers. Perhaps certain weapons development, such as all-big-gun battleships or nuclear weapons, leave a potential adversary with no choice but to match the technology or get out of the game.

Arms races that appear deterministic are not limited to the twentieth century. Some time in the eighteenth century BCE, the horse-drawn war chariot appeared on the battlefields of the Levant and swept all before it.[9] States that wanted to contend for

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[6] Paul M. Kennedy, *The Rise and Fall of British Naval Mastery* (London: Ashfield Press, 1983), 215-37. Jon Sumida has shown that Fisher actually used recent technological advances to shift Britain away from battleships and toward cruisers. See Jon Tetsuro Sumida, *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy, 1889–1914* (Boston: Unwin Hyman, 1989) and *idem*. "Sir John Fisher and the *Dreadnought*: The Sources of Naval Mythology," *Journal of Military History* 59 (October 1995): 619–38.

[7] Not counting the comparatively minor skirmish at Dogger Bank in 1915.

[8] Robert L. O'Connell, *Of Arms and Men: A History of War, Weapons, and Aggression* (New York: Oxford University Press, 1989).

[9] Arthur Cottrell, *Chariot: The Astounding Rise and Fall of the World's First War Machine* (London: Pimlico, 2004).

power had to invest in the vast and expensive infrastructure necessary to support fleets of chariots sometimes numbering in the thousands. The competition even bred an international chariot aristocracy, mercenaries who rented their skills and their equipment to the highest bidder.[10] William H. McNeill has called the chariot the "superweapon" of its day, "the supreme arbiter of the battlefield in all Eurasia.[11] More recently he has called it the "master weapon" of the second millennium BCE, a linguistic turn that invests agency in the technology itself.[12] And then, around 1200 BCE, at about the time of the "Great Catastrophe, the dominance of the war chariot evaporated in the West, even more quickly than it had materialized.[13] Historians have advanced multiple explanations for the eclipse of the war chariot, but all agree that this queen of battle was quickly relegated to transportation and ceremonial duties. Within a matter of decades, it was *hors de combat*.

The introduction of gunpowder in the West had a more prolonged and profound impact. The development of gunpowder and other explosives, along with the instruments that harnessed their energy for military and naval purposes, stretched over at least four centuries, from the fourteenth through the seventeenth.[14] In that time, the emerging Western states and some others around the world learned how to use gunpowder to defend themselves against barbarian invasion and to furthermore project their power against those lacking such weapons.[15] While many states thereafter adopted Western firearms and even turned them to good effect against the Westerners themselves, the military balance tipped strongly in favor of those states that could produce explosives and their instruments of fire.[16] Gunpowder, like the chariot, appears to have been just as deterministic in its day as the dreadnoughts and nukes of the twentieth century.

But perhaps, as Thomas Misa has argued, this is a historiographical illusion; perhaps events look more deterministic from a distance than they are close up.[17] Naval warfare, whose technology has seemed at times similarly deterministic, appears less so when examined closely.[18] The age of sail, from the late sixteenth to the late nineteenth

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[10] A. F. Rainey, "The Military Personnel at Ugarit," *Journal of Near Eastern Studies* 24 (1965): 17-27; W. F. Albright, "Mitannian Maryannu, 'Chariot-Warrior" and the Canaanite and Egyptian Equivalents," *Archiv für Orientforschung* VI (1930-31), 217-21.

[11] WilliamH. McNeill, *The Rise of the West: A History of the Human Community* (Chicago: University of Chicago Press, [1963] 1991), 102-109, quotes at 106, 104.

[12] William H. McNeill, *A World History* 4th ed. (New York: Oxford University Press, 1999),

[13] Robert Drews, *The End of the Bronze Age: Changes in Warfare and the Catastrophe ca. 1200 B.C.* (Princeton: Princeton University Press, 1993).

[14] Kenneth Chase, *Firearms: A Global History to 1700* (Cambridge: Cambridge University Press, 2003); Alfred W. Crosby, *Throwing Fire: Projectile Technology through History* (Cambridge: Cambridge University Press, 2002).

[15] Bert S. Hall, *Weapons and Warfare in Renaissance Europe: Gunpowder, Technology, and Tactics* (Baltimore: Johns Hopkins University Press, 1997); Geoffrey Parker, *The Military Revolution: Military Innovation and the Rise of the West, 1500-1800* (Cambridge: Cambridge University Press, 1988).

[16] David B. Ralston, *Importing the European Army: The Introduction of European Military Techniques and Institutions into the Extra-European World, 1600-1914* (Chicago: University of Chicago Press, 1990).

[17] Thomas J. Misa, "Retrieving Sociotechnical Change from Technological Determinism," in *Does Technology Drive History: The Dilemma of Technological* Determinism, ed. by Merritt Roe Smith and Leo Marx (Cambridge, MA: MIT Press, 1994), 115-41. **See also Spector?**

[18] See, for example, William M. McBride, *Technological Change and the United States Navy, 1865-1945* (Baltimore: Johns Hopkins University Press, 2000).

century, was dominated by a "hierarchy of power."[19] Massive ships of the line could contend with one another for command of the sea, but they were all but impervious to attack by smaller vessels. The size of the warship determined the outcome of the battle. Like the chariot of old, the sailing ship-of-the-line swept all before it. Then came Hampton Roads. The ironclad CSS *Virginia* wreaked havoc on the Union blockading vessels until it was challenged by the USS *Monitor*. The two armored steamships fought each other to a draw and leveled the hierarchy of power, or so it seemed. But the steam-powered ironclad turned out not to be as revolutionary, or deterministic, as first imagined. The *Monitor* and the *Virginia* enjoyed an advantage in the confined space of the lower Chesapeake Bay, just as other ships had exploited confined waters at the battles of Salamis (480 BCE), the Nile (1798), and Copenhagen (1801). But the iconoclastic ironclads were not yet seaworthy, and the sailing ship of the line enjoyed many more years of dominance before it was finally displaced by the all-steel, steam-propelled, screw-driven, armored battleship mounting rifled, turreted guns.[20] The transformation concluded only with the launch of the *Dreadnought*.

Still, it may appear from Thomas Misa's macro perspective that naval warfare in the nineteenth century simply exchanged one deterministic battleship paradigm for another—Admiral Horatio Nelson's *Victory* for Admiral Jackie Fisher's *Dreadnought*. But other arms races have been clearly asymmetrical and disproportional. For political, economic, and even cultural reasons, enemies have sometimes chosen to fight with dissimilar arsenals. In fact, asymmetric war became a catch-phrase of later twentieth-century American military thought.[21] In many realms of conflict, industrialized war seemed less deterministic than at any time since the introduction of the machine gun.

The most obvious case is one that has already been mentioned, submarine warfare. Naval strategy was not restricted to expensive battleship building programs aimed at some climactic contest for command of the sea. The French, for example, opted out of the battleship race and advocated a *guerre de course* built around submarines, torpedo boats, and well-armed cruisers.[22] In World War II, the major naval combatants found themselves caught in multiple paradigm shifts. The Germans opted for commerce raiding, mostly with submarines. The Americans pioneered a mixed fleet of battleships and aircraft carriers, which the Japanese attempted to shadow. The British continued to rely on the Home Fleet of battleships, while working with the Americans to develop anti-submarine warfare. The war at sea was chaotically contingent, with no single technology determining either the key to sea power or the outcome of the conflict.

Equally indeterminate was the course of land warfare. While the tank and the airplane were widely perceived as restoring mobility to warfare and dominating the battlefields of the Eurasian landmass, the outcome of World War II had far more to do with the scale of industrial production than it did with any particular weapons system. There was a larger sense, however, in which twentieth-century land war appeared to be deterministic. Total war demanded total mobilization of the state and its industrial

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19 Theodore Ropp. *War in the Modern World*, new. rev. ed. (Baltimore: Johns Hopkins University Press, 2000), 70-71.

20 Bernard Brodie, *Sea Power in the Machine Age* (Princeton: Princeton University Press, 1941).

21 Roger W. Barnett, *Asymmetrical Warfare: Today's Challenge to U.S. Military Power* (Washington, Brassey's, 2003).

22 Theodore Ropp, *The Development of a Modern Navy: French Naval Policy, 1871-1904*, ed. by Stephen S. Roberts (Annapolis, MD: U.S. Naval Institute Press, 1987).

capacity. The wealthy, industrialized states fielded a kind of mechanized army—planes, tanks, mobile artillery, logistics, etc.—capable of crushing any military force not comparably equipped.[23] Like the chariot of old, this paradigm appeared to sweep all before it. Countries had to develop like arsenals or submit.

Not so, said Mao Tse-tung. Driven on the Long March of 1936 into the mountains of Shensi Province by the western-styled and –equipped army of his erstwhile ally and current nemesis, Chiang Kai-shek, Mao contemplated how his peasant army might resist such a force. His Soviet patrons had always doubted that a Marxist Leninist revolution could succeed in an agrarian state; they imagined that the urban proletariat had to seize the capitalist means of production in order to overthrow the state. But Mao simply changed the paradigm. In constructivist terms, he restored agency to the people. What came to be called People's War was nominally formulated to drive the invading Japanese from China but really designed to win the civil war with Chiang. The soldiers of People's War avoided toe-to-toe confrontations with their enemy's mechanized army. Instead, they attacked that army in the chinks in its armor and took advantage of the limitations imposed by reliance on machines.[24]

Through the remainder of the twentieth century, other states adapted Mao's formula to their national military needs. The Vietnam War, especially its American phase from 1965 to 1973, offers the clearest example. But many other wars and insurrections in Asia, Africa, and Latin American pitted rural, agrarian insurgents against urban-based armies equipped with Western-style arms and armor.[25] Because so many of these wars were proxy conflicts in the Cold War between the Soviet Union and the United States, it sometimes appeared that both sides enjoyed a kind of arms symmetry. Soviet-backed insurgents fired AK-47s at government forces armed with American M-16s. But in most cases the government forces had advantages in heavy weapons—airplanes, tanks, artillery—that the insurgents could not match. The rebels used the tactics of People's War to level the playing field.

Military history provides many other examples in which the choice of weapons appears not to have been deterministic. In addition to the naval transition from sail to steam and the introduction of People's War, the infantry tactics of Swiss pikemen in early modern Europe often unseated the mounted warriors of the feudal array. The side-gunned, ocean-going sailing vessels at the battle of Lepanto differed dramatically from the great Mediterranean galleasses they defeated. The lightly armed and armored mounted soldiers of the Eurasian plain always differed from the massed infantry and heavy cavalry they encountered in the civilizations of Europe and Asia. The Cold War fighter aircraft of the Soviet Union emphasized speed at all costs, while their American counterparts relied on maneuverability and systems sophistication. In countless wars throughout history, the duelists chose different weapons and fought asymmetrical wars shaped by their choices.

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[23] Walter Millis asserted in *Arms and Men* that the internal combustion engine was the dominant technology of World War II, but one would hardly call it deterministic. Walter Millis, "The Mechanization of War," in *Arms and Men: A Study in American Military History* (New Brunswick, NJ: Rutgers University Press, [1956] 1986), 211-64.

[24] Mao Tse-tung, "On Protracted War" (May 1938) at http://www.marxists.org/reference/archive/mao/selected-works/volume-2/mswv2_09.htm, accessed 10 Sept. 2007.

[25] Patrick Brogan, *The Fighting Never Stopped* (New York: Vintage, 1990).

But so too does history offer many examples of seemingly deterministic arms competitions. In addition to the nuclear arsenals of the Cold War and the Anglo-German naval race preceding World War I, land and naval mines have been embraced by aggressors and defenders alike, by strong states and weak. Machine guns appeal universally. Soldiers everywhere are learning to use American global-positioning technology for their own purposes. No self-respecting armed force any longer enters contested ground without shoulder-launched rockets. If combatants do not always mimic each other's arsenals, they at least shop in the same international arms bazaar.[26]

So must we conclude that sometimes arms races are deterministic and sometimes not? And if so, can we discern any patterns suggesting why they take one form or another? The problem appears to have two parts. First, the question may be formulated improperly. The categories of analysis: arms races, symmetry, proportionality, war, etc. might be wrong. Also, the normal conceptual tools might be flawed. Perhaps "technological determinism" lacks explanatory power.

Despite an early fascination with technological determinism, the SHOT community has spent most of its fifty years disparaging the concept. Paul Forman believes that we generally view technological determinism as "heresy." Rosalind Williams calls it "forbidden fruit," and Rachel Laudan has taken this rejection of the phenomenon to be our "official posture."[27] Thomas Misa has said that "no greater crime can be imagined" within our community than advocacy of technological determinism.[28] Eric Schatzberg asserted in 1999 that "no prominent historian of technology today would admit belief in technological determinism," a claim that seems to answer David Edgerton's rhetorical question "Who is the last 'technological determinist of significance"?[29]

Well, how about Rosalind Williams, Paul Ceruzzi, or Thomas Misa? None of them would quite label themselves technological determinists (for reasons I will discuss shortly), but all of them have been willing in recent years to violate the taboo that seems to surround the subject.[30] Merritt Roe Smith and Leo Marx thought the topic sufficiently important to warrant a conference from which they published an important collection of essays. The public at large seems increasingly enamored of technological determinism,

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[26] Anthony Sampson, *The Arms Bazaar: From Lebanon to Lockheed* (New York: Viking, 1977).

[27] Paul Forman," The Primacy of Science in Modernity, of Technology in Postmodernity, and of Ideology in the History of Technology," *History and Technology* 23 ((March/June 2007): 1-152, at 65; Rosalind Williams, "Opening the Big Box," *Technology and Culture* 48 (Jan. 2007):104-116, at 104; Rachel Laudan, "Natural Alliance or Forced Marriage? Changing Relations between the Histories of Science and Technology," *Technology and Culture*, 36 (1995), S17-28, at S19.

[28] Thomas Misa, "Beyond Linear Models: Science, Technology, and Processes of Change," in *The Science-Industry Nexus: History, Policy, Implications: Nobel Symposium 123*, ed. by Karl Grandin, Nina Wormbs, Sven Widmalm (Sagamoe Beach, MA: Science History Publications, 2004), 263.

[29] Eric Schatzberg, "Undermining Common Sense: The Critique of Technological Determinism in History of Technology Courses," at http://www.cals.wisc.edu/iic/innovation/schatzberg.html, accessed 15 Sept. 2007; David Edgerton, *Warfare State*, 333n.

[30] Williams, "Big Box," ;Paul Ceruzzi, "Moore's Law and Technological Determinism: Reflection son the History of Technology," *Technology and Culture* 46 (2005): 584-93 ; Misa, "Beyond Linear Models," 262-64.

as do some other disciplines.[31] In fact, Paul Forman believes that historians of technology have been blinded by their faith. In our compulsion to dismiss and discredit technological determinism, he says, we have failed to appreciate and illuminate the enormous impact of technology on modern (and postmodern) life.[32]

"Technological determinism" remains a vexed and toxic term within our field. The reason, I think, is that it is not really a category of analysis but an intentionally opprobrious term of scorn. It is invoked not to illuminate, but to demean. It is not a tool, but a weapon. "Technological determinist" is not a title one claims for oneself, but an epithet that one casts at an opponent.[33] "Technological determinism" is not a historical phenomenon so much as a vile slander used to caricature someone's historiographical position.

The reason, of course, is that **nothing** in human experience is deterministic. Nothing makes an outcome inevitable. Not even death and taxes are certain. Countless wealthy people pay no taxes at all and "cheating" death is a commonplace of Western culture. Just as we doubt single-causation explanations of any human phenomenon, so are we loath to accept that anything is predetermined. Inevitability implies some natural law pushing events to a predetermined end. Until a technological determinist can articulate and prove such a law, historians will dismiss determinism with the disdain it deserves. It is not just that historians of technology reject technological determinism. All historians reject all determinism, and rightly so.

Then why have this discussion at all? Why not simply aver that arms races are not deterministic because no human activity is deterministic? Well, because there really is something about technology that can, under certain circumstances, exert a powerful force on the course of historical events. That something takes on two separate forms, both of which have sometimes been lumped under the single heading of "technological determinism." There is, first of all, a sense in which some technologies in some contexts shape society and push historical events in directions they would not otherwise have taken. Many historians have attempted to find a term for this phenomenon other than "technological determinism." Thomas Hughes has called it "momentum."[34] Rosalind Williams recently recommended Raymond Williams' formulations of "setting bounds and exerting pressures."[35] Some have suggested "soft determinism," a mirror image of the semantic debate taking place at the other end of the ideological spectrum in the realm of "hard SCOT" (Social Construction of Technology) and "soft SCOT"

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[31] Langdon Winner, "Where Technological Determinism Went," in *Visions of STS: Counterpoints in Science, Technology, and society Studies*, ed. by Stephen H. Cutcliffe and Carl Mitcham (Albany: State University of New York Press, 2001), 11-17; *idem*., "Technological Determinism: Alive and Kicking? *Bulletin of Science, Technology, and Society* 17 (1997): 1-2; Christopher Freeman, "The Case for Technological Determinism," in *Information Technology: Social Issues: A Reader*, ed. by Ruth Finnegan, Graeme Salaman, and Kenneth Thompson (Seven Oaks: Hodder and Stoughton, 1987), 5-18.

[32] Forman, "Primacy of Science." I am greatly indebted to Paul Forman for his penetrating analysis of this and other topics in the historiography of science and technology.

[33] Thomas Misa says that we historians of technology have "a pervasive wariness of being branded by our peers as a technological determinist." Misa, "Beyond Linear Models," 263.

[34] Thomas Parke Hughes, "Technological Momentum: Hydrogenation in Germany, 1900-1933), *Past and* Present (August 1969): 106-132; *idem*., "Technological Momentum, " in *Does Technology Drive History? The Dilemma of Technological Determinism*, ed. by Merritt Roe Smith and Leo Marx (Cambridge, MA: MIT Press, 1994), 101-113.

[35] Williams, "Opening the Big Box," 114.

(contextualization).[36] Lynn White, in an essay widely denounced as advocating technological determinism, invoked a metaphor. He said that technologies can open doors to new human possibilities, but they cannot make anyone walk through.[37]

Some scholars have suggested the term "technological imperative." This has the great virtue of suggesting that the force is obligatory, it commands some action. The internal combustion engine, for example, commands us to scour the world for petroleum. But rules were meant to be broken, and commands are bound to be disobeyed. Human agency still exists. People can chose whether or not they want to pass through the door opened by Lynn White's stirrup. By removing inevitability from the formulation, the imperative captures something of the force that technology can exert on society without insisting that the force is irresistible.

Alas, "technological imperative" has also been enlisted for another purpose, one that muddies its potential use as an alternative to "technological determinism." "Technological imperative" is often used to identify a different meaning of "technological determinism." This is determinism not of technology's impact on society, but of the trajectory along which the technology will develop. "Technological imperative" in this sense means that airplanes will fly higher, faster, and farther; computer chips will keep increasing in relative capacity; genetic engineering will move toward human cloning whether we want it or not; and nuclear superpowers will choose bombers, ICBMs, and SLBMs. This is the technological determinism that Donald MacKenzie was deconstructing in *Inventing Accuracy*. It is the determinism of Langdon Winner's "autonomous technology."[38] It is the phenomenon that economic historians have called "path independence."[39] It is the determinism that John Staudenmaier and other scholars warn against when describing the advances of Western science and technology as "progress."[40] As a category of analysis, it is teleological and circular;

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[36] At the 1993 conference at Oxford on technological change, Trevor Pinch challenged his audience to name a single technology that was not socially constructed. Walter Vincenti rose to propose retractable landing gear. The logic behind Pinch's challenge was that all technologies are made by people; they are socially constructed by definition. Vincenti's point was that regardless of time, place, or individuals involved, all aviation designers and manufacturers have settled upon the same technology for landing gear on aircraft. Retractable landing gear have arguably exerted an irresistible technological imperative to the aeronautical community around the world. Note that Hughes made determinism and social construction polar opposites in what was almost a confession of faith, distancing himself from determinists such as Karl Marx, Lynn White, Jr., and Jacques Ellul. Hughes, "Technological Momentum," 103.

[37] Lynn White, Jr., *Medieval Technology and Social Change* (London: Oxford University Press, 1962). See also Alex Roland, "Once More into the Stirrups: Lynn White jr., *Medieval Technology and Social Change*," Technology and Culture 44 (July 2003): 574-85.

[38] Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, MA: MIT Press, 1977).

[39] R. Nelson and S. Winter, *An evolutionary Theory of Economic Change* (Cambridge, MA: Harvard University Press, 1982); W. Brian Arthur, *Increasing Returns and Path Dependence in the Economy* (Ann Arbor, MI: University of Michigan Press, 1994); Paul A. David, "Path Dependence, Its Critics and the Quest for 'Historical Economics,'" in *Evolution and Path Dependence in Economic Ideas: Past and Present*, ed. by P. Garrouste and S. Ioannides (Cheltenham, Eng.: Edward Elgar Publishing, 2000).

[40] John M. Staudenmaier, S.J., "Perils of Progress Talk: Some Historical Considerations," in *Science, Technology and Social Progress*, ed. by Stephen L. Goldman (Bethlehem, PA: Lehigh University Press, 1989), 268-93. Some scholars and disciplines use "technological imperative" to refer to technology's impact ton society. See, for example, M. Lynne Markus and Daniel Robey, "Information Technology and

seldom can we say where a technology is bound to go until it has gone there. Scholars of modern medicine see both determinisms at work in their field of study: medical technology keeps getting more sophisticated and more expensive (technological imperative) and doctors cannot resist prescribing the latest procedures and interventions (technological determinism).[41] But historians of technology have treated the concept "technological imperative" with almost the same opprobrium that they attach to "technological determinism" in the form of technology bending society to its purposes.

So, what is to be done? The Cold War arms race between the Soviet Union and the United States suggests that something in the nature of strategic nuclear weapons drove both sides toward the development of proportional and symmetrical arsenals and that the development of the arsenals bred national security states, what Harold Lasswell called "garrison states."[42] But historians of technology have neither a vocabulary nor a paradigm to explain this phenomenon. If we are to believe Paul Forman, this lack of conceptual tools flows from our ideological predispositions and our institutional parochialism.

At the risk of appearing anti-intellectual, I would like to suggest that we stop using labels such as "technological determinism" and simply examine the **social force** and **directional force** of specific technologies in specific historical contexts. Social force is the impact of technology on society. It may be strong or weak, depending on the circumstances. Directional force is the tendency of a technology to develop along a particular trajectory. This, too, maybe strong or weak, depending on the historical context. The race to ever more powerful computer chips has been strongly directional over the decades since Gordon Moore hypothesized his law.[43] This is no guarantee that it will continue on that trajectory very far into the future. Meanwhile, other technological developments, such as home entertainment and personal communication have been far more volatile and contingent. Sometimes, from some perspectives, the social force may appear deterministic, but let us resist the temptation to label it as such. And sometimes from some perspectives, the directional force may appear linear and self-governing, as if obeying some technological imperative. But let us resist that formulation as well. As microfilm recedes before digitalization, as television succumbs to the internet, and as the DVD gives way to MP3, we are surrounded by reminders of the ephemerality of inevitability.[44]

Viewed in this light, the Cold War nuclear arms race between the United States and the Soviet Union was a unique historical event. Technology was a powerful driver,

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Organizational Change: Causal Structure in Theory and Research," *Management Science* 34 (May 1988): 583-598.

41 The concept appears to have particular appeal in the medical and educational communities. See, for example, Barbara A. Koenig, "The Technological Imperative in Medical Practice: The Social Creation of a 'Routine' Treatment," in *Biomedicine Examined*, ed. by Margaret Lock and Deborah Gordon (Dordrecht: Kluwer Academic Publishers, 1988), 465-96.

42 Alex Roland, "The Grim Paraphernalia: Eisenhower and the Garrison State," in Forging the Shield: Eisenhower and National Security in the 21st Century, ed. by Dennis Showalter (Carson City, NV: Imprint Publications, 2005,) 13-22.

43 Ceruzzi, "Moore's Law."

44 It may well be that we will one day look back upon our current enthusiasm for digitalization of data with the same wonderment.

both of the way the two societies organized themselves to compete and the direction in which their arsenals evolved. But their decisions in both cases were not determined by the technology of nuclear weapons and strategic delivery systems. Rather, those technologies opened doors that the two sides evaluated by their own lights. They walked through some and turned away from others. In every case, their decisions were similar but not identical.[45]

One conclusion from this rumination is that we could profitably talk about the circumstances in which technologies are more or less likely to have a strong or weak social force, or a strong or weak directional force. The arms race in strategic nuclear weapons had a strong social force and a moderate directional force. The United States was always trying to break away; the Soviets always kept up, until Star Wars.

The social force acted along multiple axes. The deterrent effect of the nuclear arsenals amassed by the United States and the Soviet Union offers the best explanation for what John Lewis Gaddis has called "the long peace."[46] Great power war ended with World War II and seems unlikely to resume in any foreseeable future.[47] With nuclear weapons and the array of delivery systems developed during the Cold War, hostilities between nuclear states became, in Herman Kahn's word, "unthinkable."[48] Of course, other factors contributed to the eclipse of great-power war: the United Nations, globalization, regional security compacts, and the sheer destructiveness of even conventional war. But the confrontation between the United States and the Soviet Union nonetheless represents the first time in history when two superpowers with conflicting international agendas came within reach of each other without using war to resolve their differences. It is not unreasonable to conclude that their arsenals of deterrence deterred.

A second social force unleashed by the nuclear arms race was what historian Spencer Weart has called "nuclear fear."[49] Especially during the 1950s and the early 1960s, the devastation of Hiroshima and Nagasaki, the increased destructiveness of thermonuclear weapons, the brinksmanship culminating in the Cuban Missile Crisis, and the spread of nuclear capabilities to other countries such as China heightened the sense in many quarters that nuclear war was inevitable and it might well extinguish human life on Earth. In retrospect, it is clear that both fears were exaggerated, but they were nonetheless real for that. Furthermore, they spread into other realms and helped to shape, for example, the response to commercial nuclear power in many countries around the world.

Third, the nuclear arms race between the Soviet Union and the United States taxed the economies of both countries and diverted national resources from other more

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45 There are not really that many cases analogous to Walter Vincenti's retractable landing gear.

46 John Lewis Gaddis, *The Long Peace: Inquiries into the History of the Cold War* (London: Oxford University Press, 1987); Alex Roland, "Keep the Bomb," Technology Review (August/September 1995): 67-69.

47 Jack S. Levy, *War in the Modern Great Power System, 1495-1975* (Lexington: University of Kentucky Press, 1983).

48 Herman Kahn, *Thinking about the Unthinkable* (New York: Horizon Press, 1962). See Sharon Ghamari-Tabrizi, *The Worlds of Herman Kahn: The Intuitive Science of Thermonuclear War* (Cambridge, MA: Harvard University Press, 2005).

49 Spencer Weart, *Nuclear Fear: A History of Images* (Cambridge, MA: Harvard University Press, 1988).

fruitful lines of public investment.[50] Stephen I. Schwartz and his colleagues at the Brookings Institution estimate that the United States spent almost $5.5 trillion (in 2006 dollars) on nuclear weapons development, production, and deployment between 1940 and 1996. The meaning of such numbers is unfathomable except by comparison. This investment represents less than the United States spent on defense in total and on social security in the same period, slightly more than the country spent on welfare and interest on the national debt. In the realm of national security, however, it was a comparative bargain, accounting for only about 15 percent of the $18.7 trillion the U.S. spent in the same period. Because the Soviet Union had a much smaller economy than that of the United States, it had to invest a much larger percent of its national treasure in the arms race, no doubt contributing to its ultimate collapse. On both sides, the major cost was not the nuclear weapons themselves, which consumed only 7 percent of American nuclear spending, but the delivery systems, which consumed more than 70 percent of that spending.[51]

A comparable impact on society of the nuclear arms race was environmental. Schwartz and his colleagues estimate that the price of environmental recovery from the nuclear weapons programs of the United States and the Soviet Union will equal or exceed by 2070 the costs of producing and deploying the weapons. And some of the environmental impact is irreversible, including the effects on humans and animals from the fallout from atmospheric testing in the 1950s and early 1960s. The equivalent of 16,250 Hiroshima-sized bombs was exploded above ground by the Soviet Union and the United States before the Nuclear Test Ban Treaty of 1963 went into effect.[52]

The other major impact on society of the nuclear arms race was cultural. The mushroom cloud became something of an icon of the nuclear age, and the prospect that the human race might bomb itself into extinction fed—if it did not provoke--the post-modern malaise of the late twentieth century.[53]

Most of these phenomena—spiraling defense spending, nuclear fear, post-modern malaise—contributed to the sense in the late twentieth century that bombs were in the saddle and society had to follow, even to the ends of the Earth. The memorable image at the end of the movie *Dr. Strangelove* in which Slim Pickens rode his nuclear bomb to oblivion on its target in the Soviet Union dripped with irony for just this reason. He was not steering the bomb, of course, but riding it toward a sunset scripted by the weapons themselves. Only toward the end of the Cold War did the world begin to grasp the enormity of the environmental consequences of the nuclear arms race. And only after that have some scholars come to see that the arms race may well have saved the world from a worse fate: World War III. But for good or ill, there was no denying that the

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[50] Paul Forman, “Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940-1960,” *Historical Studies in the Physical Sciences* 18 (1987): 149-229; Paul Forman and José M. Sánchez-Ron, eds., *National Military Establishments and the Advancement of Science and Technology* (Dordrecht: Kluwer Academic Publishers, 1996).

[51] Stephen I. Schwartz, ed., *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940* (Washington: Brookings Institution Press, 1998). See also *idem*, “The Hidden Costs of Our Nuclear Arsenal,” *Global Politics* (1998), at http://www.brook.edu/fp/projects/nucwcost/schwartz.htm, accessed on 13 August 2007.

[52] Schwartz, “Hidden Costs,” 5.

[53] Peggy Rosenthal, “The Nuclear Mushroom Cloud as Cultural Image,” *American Literary History* 3 (Spring 1991): 63-92.

weapons piped a compelling tune for society through much of the Cold War, that their social force **seemed** irresistible.

On the other hand, an equally compelling argument can be made for social construction. After all, humanity did manage to keep its nuclear weapons sheathed throughout the Cold War and beyond. It did manage to impose upon them safeguards that averted the nightmarish accidents often predicted by their critics. It did manage to put in place a surprisingly successful non-proliferation regime that retarded the spread of these weapons and their associated technologies. The superpowers did conduct a series of arms reduction agreements that have seen the world's stockpile of nuclear warheads shrink from more than 70,000 in 1986 to less than 29,000 in 2006.[54] One may wish that human agency had asserted itself sooner and more forcefully, and that it would move in the future toward elimination of these weapons, but it can hardly be said in retrospect that the nuclear arms race was deterministic. People designed, built, deployed, used, safeguarded, and partially dismantled these weapons without the catastrophe that many technological determinists had predicted.[55]

What about directional force? Were nuclear weapons autonomous? Was their development somehow path independent, moving inexorably to the enormous, parallel strategic systems deployed by the United States and the Soviet Union at the height of the Cold War? Were they driven by some technological imperative to mimic each other in size and type? Well, yes and no. As with Tom Misa's concept of perspective, this phenomenon looks deterministic or imperative from afar, much less so on closer inspection. This holds true for both the nature of the launch systems and the size of the arsenals.

As noted above, both sides developed a triad of strategic nuclear systems: bombers, ICBMs, and SLBMs. The development of these arsenals, however, was path dependent. The United States took the lead in bomber development, because it had built up that technology for conventional war in the 1930s and 1940s. Furthermore, it ended World War II with a ring of overseas air bases from which it could bomb targets deep within the Soviet Union. The Soviets imitated the American weapons system, though their bombers never had the range or the forward bases to make this threat credible.[56]

For these reasons, when the Americans and the Soviets captured the German rocket scientists and their hardware at the end of World War II, they chose to use these assets differently. The Soviets began in 1947 to develop a ballistic missile that could reach the United States. The Americans deferred development of the ICBM, relying instead on its incomparable bomber fleet and bases and its monopoly of atomic

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[54] National Resources Defense Council, "Global Nuclear Stockpiles, 1945-2006," *Bulletin of the Atomic Scientists* (July/August 2006): 64-66.

[55] Admiral Noel Gayler argued in the 1980s that nuclear war was inevitable if the weapons were not eliminated. His logic was that the risk of nuclear accident or attack, however small, was finite. Therefore, mathematically, if nuclear weapons existed long enough, a disaster would occur. This surmise neglects the fact that the sun might die before the catastrophe occurred, or the human race might have gone extinct. Personal between Admiral Gayler and the author, Washington, DC, 26 Oct. 1987. For the context, see Martin Harwitt, *An Exhibit Denied: Lobbying the History of* Enola Gay (New York: Copernicus, 1996), 30-34.

[56] Save, of course, for the famous "bomber gap" of 1955-57, in which the Soviets tricked American intelligence into believing they had a massive fleet of bombers by flying the same planes repeatedly over events attended by Western observers.

weaponry. When American intelligence discovered in the mid-1950s that the Soviets were nearing success with an ICBM, the U.S. launched its own crash program to catch up. Thereafter, the Soviets always had the advantage over the United States in the power ("throw-weight") of its missiles—they were designed to carry the heavy atomic weapons of the 1940s and early 1950s, not the comparatively light thermonuclear weapons introduced in 1952 and 1953—while the United States had smaller but more sophisticated missiles.

The third leg of the triad, SLBMs, was a wholly American invention, largely a product of interservice competition between the U.S. Air Force and the U.S. Navy. The Air Force (newly created in 1947) was funded through the first decade of the Cold War at a higher rate than the Army and Navy combined. The Navy concluded that it would have to capture some share of the strategic nuclear mission if it was to compete for appropriations. So, it developed a radical, solid-fuel ballistic missile, the Polaris, which could be carried aboard nuclear-powered submarines. Once the technical problems of solid-fuel rockets were overcome, even the Air Force changed over to that technology. More importantly, the Soviet Union developed its own fleet of ballistic-missile submarines, to ensure that the United States did not enjoy exclusive possession of a delivery system of war-winning potential. The dueling superpowers behaved like racing yachts, tacking in unison to ensure that the opponent did not sail off into some fresh wind or smooth seas.

Thus, the three main arms of each nation's strategic arsenal came to resemble each other, not so much because of the inevitability of these weapons systems as because of the impulse of each side to match the other. Throughout the Cold War, however, the United States tried to break out of the stalemate. It perfected cruise missiles, which flew close to the ground (below radar) instead of in ballistic arcs, and mounted them on airplanes, ships, and even ground vehicles. The Americans experimented with space-based weaponry, until both sides agreed in the space treaty of 1967 not to place weapons of mass destruction in space. The Americans improved the accuracy of their ICBMs and matched the capability with unparalleled targeting information gleaned from reconnaissance satellites. They placed multiple warheads on the same missile (MIRVs) and made some of the multiple warheads maneuverable (MARVs). And finally, in the climax of the Cold War, they undertook a major development program for ballistic missile defense.[57] In almost all of these cases, the United States innovated and the Soviet Union imitated, or tried to. Despite these permutations, the two arsenals still looked very similar at the end of the Cold War. Nevertheless, it is clear that no technological imperative drove those similarities. They were driven by the nature of the competition between the two superpowers, especially the faith of the United States in advanced technology as the key to security.

In the search for a technological imperative, a better case can be made for the thermonuclear bomb than for the delivery systems that carried it. Both sides understood in the 1940s that a fusion bomb had far greater energy potential than the fission weapons of Hiroshima and Nagasaki, and each side began a development program independently of whether the other side could or would do the same. It is a nice question whether the

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[57] Frances FitzGerald, *Way Out There in the Blue: Reagan, Star Wars, and the End of the Cold War* (New York: Simon & Schuster, 2000); Donald R. Baucom, *The Origins of SDI, 1944-1983* (Lawrence: University of Kansas Press, 1992).

Soviets imitated the American hydrogen bomb the way they imitated the atomic bomb and so many of their delivery systems. But the two sides succeeded in exploding their first thermonuclear weapons within months of each other. The lure of this technology proved irresistible to both. In economic terms, the development of the hydrogen bomb appears to have been path independent.[58]

Nor did the enormous scale of the superpowers' arsenals flow from the nature of the technology. It flowed from the nature of arms competition. Deterrence had its own MAD logic. Security came from vulnerability. As long as each side was vulnerable to retaliation, neither side would launch a first strike The weapons would be successful only if they were never used. Each side had to believe that no matter what it did to the other side, even a sneak attack, retaliation would follow. Since there was no realistic defense against ballistic missiles and no sure way to neutralize all the enemy's weapons before they were fired, security came in numbers. The more weapons each side had, the greater the chance that there would be enough left after a first strike to retaliate decisively. Thus, each side had an independent incentive to increase the number of its warheads, and each increase by one side bred a comparable increase by the other. This was driven in part by the nature of the technologies and in larger part by human nature.[59]

In sum, the nuclear arsenals of the United States and the Soviet Union exerted a social force on each country and a directional force in the development of their arsenals. But the two countries shaped the arms race more than they were shaped by it, and the two arsenals had more to do with human nature and competition than they did with the autonomy of the technologies themselves. As in all arms races, as indeed in all human competition—military, economic, athletic—the technologies in play shaped their environment and shaped their own evolution, but they did not determine either one. This arms race was not deterministic. No arms race is deterministic. No technology is deterministic. No historical phenomenon is deterministic. "Technological determinism" is a rhetorical, not an analytical, tool

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[58] At least after the failure of the Baruch Plan.

[59] Robert Jervis, "Was the Cold War a Security Dilemma?" *Journal of Cold War Studies* 3 (Winter 2001): 36-60.