

RATIONALITY, AGENCY, CONTINGENCY: RECENT TRENDS IN THE HISTORY OF TECHNOLOGY

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When the Society for the History of Technology (SHOT) launched itself in the late 1950s, many U.S. historians found a compelling postwar framework for organizing research around an American consensus. SHOT's founding generation participated in the scholarly spirit of the time although with its own particular emphases. Cold War ideology and a morally idealistic engineering creed defined technology, if well funded and untethered by local political passions, as leading in a clean line toward democratic societies. Apart from this technologically specified version of American hegemonic progress, the received stereotype for technological history in the 1950s was no interpretation at all. Half a millennium of curiosity about artifacts had crystallized in a balkanized landscape, islands of passionate attention to minute changes over time in one's artifact of choice—clocks, trains, automobiles, machine tools, weapons. An antiquarian paradigm and compelling Cold War urgency marked SHOT's beginnings as a (barely) visible discipline in 1958.¹ Still, a handful of landmark books had begun to suggest new directions. Lewis Mumford and Siegfried S. Giedion, in particular, achieved an international reputation for major synthetic interpretations of western technological style. Louis Hunter's *Steamboats on the Western Rivers* and I. B. Holley's *Ideas and Weapons: Exploitation of the Aerial Weapon by the United States During World War One* were less broadly known but considered breakthrough works within SHOT, comprehensive histories that situated technologies in the rich economic and political context of their times.² The founders understood their journal title as a move from internalism toward the still inchoate approach seen in Mumford, Giedion, Holley, and Hunter. The new journal would emphasize context: *Technology and Culture*.

Two principles more or less defined their emerging methodology. First, every technology has a context of origin. Historical actors, specific in motive, worldview, and resources, shape technologies, as does the ambient social order. Second, technological actors think distinctively; from the beginning, historians of technology almost unanimously rejected the received popular notion of technology as "applied science." Engineers use science as one

cognitive tool among several in a pragmatic blend of theoretical expertise and experiential judgment.

By 1980 consensus in the field appeared to flatly contradict the Cold War paradigm. The notion of autonomous technological progress, itself the application of an equally autonomous science and operating free from historical context had been supplanted by what came to be known as "contextualism." During these same years, however, several working assumptions suggested the latent power of the Cold War model. Patterns of research site selection and, in particular, topics seldom studied and questions rarely asked, reveal a shadow consensus. "Technology," as described by the patterns of research sites, neatly fit the chronology and geography of Western Civilization courses taught in universities at the time. Historians of technology concentrated largely on strategically successful actors: engineering, entrepreneurial, and managerial types who created technologies and moved them to market. Once launched, the technologies seemed less interesting. New technology success stories appeared much more frequently than failure stories or studies of technologies in ordinary use. Technological cognition often seemed straightforward and strategic: define a goal, marshal resources to achieve the goal, and address obstacles as they turned up along the way. Other actors—wage workers, consumers, non-westerners, women—appeared in these accounts, if at all, as deep background, their voices muted.³ Historians of technology were typically male and lived in the United States or Great Britain. "Getting it right," a minimal competency for SHOT historians, meant understanding how material constraints influence outcomes. Understanding what goes on inside black boxes gave historians of technology something of the character of early ham radio operators, hot rodders and computer scientists, a close knit fraternity with an arcane wisdom.

These are, to be sure, excessively delineated assertions with exceptions at every point. Nonetheless, they suggest a profile of the field in these years as simultaneously creative and narrow. The thin clean line of progress, Western science and technology leading to democracy, legitimated a mentality that brushed aside perspectives from outside the design plan as interruptions calling for deft management rather than voices requiring change in concept. The West had emerged from World War Two with a fistful of technological and scientific trump for the game of global dominance that followed. Wartime research and development seemed to argue for giving experts as free a hand as possible to design immensely complex systems for domestic markets and national defense. Given their origins in the engineering community, it is hardly surprising that historians of technology in the founding generation mostly wrote narratives congruent with the spirit of the time.

True enough. Still, powerfully subversive seeds were germinating in these years. SHOT's contextual commitment looks, now forty years later, to have

been more influential than the Cold War triumphalism of the founding era. If we use the early 1980s as a break point, we find SHOT's already notable intellectual heft in a number of model contextual studies whose range and depth of scholarship marked them as defining masterworks for a profession dedicated to understanding how complex technologies actually work and why they take the forms they do. These core books integrated creative excellence with the vagaries of human behavior. Taken as a coherent body of discourse (most in SHOT read most of these), their contextualism implied that clean-line narratives were subject to interrogation.⁴ Little by little, after 1980, interrogating the master narratives of progress went from being daring, to acceptable, to commonplace. Besides mirroring patterns in the larger historical profession, SHOT's critical turn warrants attention on two counts, both specific to the history of technology. On the one hand, respect for the inside of black boxes, a commitment SHOT has never lost, meant that critiques of the "progress" story take a laborious route, seeking historical contingency deep in the gears and circuit boards of technological design itself. SHOT scholars require literacy (if not fluency) with the operational constraints of the technologies they study.⁵ On the other hand, the sheer iconic power of the word "technology" makes it a contested term in public discourse and influences the intellectual climate in which historians of technology work. Who gets to define its meaning? In this culturally charged arena, historians compete with op-ed page essayists, corporate advertisers, members of Congress, and the imaginers at Disney's EPCOT center. In sum, changes in the field since 1980, the subject of the remainder of this essay, emerged in a context marked by a shared commitment to the historical importance of technological design constraints and by the cultural cross winds generated by the symbolic power of its subject matter.

The conviction that the inside of the black box matters, likely cause of SHOT's small-club isolation, remains strong today.⁶ Nonetheless, the past ten years fairly bristle with signs of SHOT's move into larger worlds of discourse. The first offerings of the AHA-SHOT booklet series, Francesca Bray's *Technology and Society in Ming China*, Pamela O. Long's *Technology, Society, and Culture in Late Medieval and Renaissance Europe* and Alex Roland's *The Military-Industrial Complex*, will soon be followed by six more.⁷ Besides SHOT's traditional relationships with the History of Science Society and the Society for the Social Studies of Science, historians of technology have become highly visible in what only a few years ago would be called, at best, neighboring fields. Thus, people as central to SHOT as Phil Scranton, David Hounshell, and Pamela Walker Laird contribute prominently to the Business History Conference.⁸ In like fashion, historians of technology and environmental historians have established strong relationships in the recent past. In 1998, Joel A. Tarr and Jeffrey K. Stine published an influential survey of environ-

ment-technology historiography in T&C and environmentally oriented manuscripts began to appear regularly in its pages.⁹ Agricultural history, long dominated by economic historians, begins to show the influence of several senior historians of technology, including Deborah Fitzgerald and Ronald Kline. An agricultural history focus is emerging in the work of junior scholars as well.¹⁰ Besides this recent cross-line energy among subdisciplines, major academic conferences have become commonplace in the past decade as funding agencies on both sides of the Atlantic show increasing respect for technological questions. These new influences, working in creative tension with SHOT's still-robust contextual scholarship, look to be transforming the field. I will address the most compelling trends under two methodological questions of increasing importance for SHOT: who occupies the center of the narrative frame and what place should theory and epistemology have in historical narrative?

Who belongs in the center of the narrative frame? Most observers agree that SHOT's older template—engineers, designers, investors, entrepreneurs, and managers holding the center pretty much to the exclusion of other actors—no longer dominates research. The older cast of characters remains important but they share the stage with a host of once-marginal figures. Bringing new actors to the center of the narrative frame begins to reveal the inherently contingent nature of technological definition. Who gets to say what "the technology" is? Engineers? Investors? Consumers? Factory workers? Farmers? African Americans? The implications of this new traffic jam at the center of the narrative frame are profound. Most SHOT members would agree that designers and investors still require attention but the latent assumption that a technology ceases to be of much interest once launched has been turned on its head. For a growing number of historians of technology, the move into the world of ordinary use—Ruth Schwartz Cowan's "consumption junction"—is precisely when a technology gets interesting.¹¹ When the defining time frame for a technology's story extends out into the tangle of the human condition, whole realms of often-overlooked technological practice begin to be intelligible. Trevor Pinch and Ron Kline find that farmers creatively redefined the Model T. Sometimes users thwarted manufacturer intent (buying accessories from independent vendors) and sometimes they led manufacturers back to the design table, as when Ford introduced the Fordson tractor to compete with its own Model T (when modified with tractor make-over kits).¹²

By far SHOT's most important class of new actors is women. SHOT's move toward gender balance from an almost all-male universe of both historians and topics predates Ruth Schwartz Cowan's groundbreaking *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave* (1983) by a half decade.¹³ Still the book's elegant thesis and high profile

undoubtedly helped stimulate the remarkable growth of SHOT's gender research.¹⁴ Women appear in recent histories of technology sometimes as consumer decision makers, as in Joy Parr's "What Makes Washday Less Blue," sometimes as workers as in Roger Horowitz's "Where Men Will Not Work" or Kenneth Liparito's study of telephone operators, "When Women Were Switches."¹⁵

Even some of SHOT's most neglected research areas begin to show the influence of SHOT's longer narrative time frame and broader cast of characters. Until recently, historians of technology have been less than diligent about non-Western actors and race and class. There were exceptions, most notably Daniel R. Headrick whose *Tools of Empire* (1981) marked the first of his monograph series on colonialism and imperial competition. Other senior scholars originating in other disciplines have found welcome in SHOT for research into non-Western technology: Michael Adas's *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance* (1989) and Francesca Bray's *Technology and Gender: Fabrics of Power in Late Imperial China* (1997) both won SHOT's Dexter Prize. Today, however, historians of technology who adopt non-Western perspectives are typically younger and in the early stages of major projects. Gabrielle Hecht is building on her AHA prize-winning *The Radiance of France: Nuclear Power and National Identity after World War II* (1998) by following the trail of nuclear technology to uranium mining sites in Africa, Australia, and the southwestern United States, asking how mining colonies and local native cultures intersect. Suzanne Moon treats the Cold War strategies of the U.S. State Department and the Indonesian government (over tractors for rice cultivation) as central but they share narrative space with rice farmers on the ground.¹⁶

Race-and-ethnicity studies begin to be less scarce than heretofore. Two well-received new books, by Judith Carney and Venus Green, were introduced to SHOT readers in earlier T&C articles. Carney convincingly argues that pre-slave trade Africans created and developed a sophisticated tidalwater rice cultivation system that, under slave tutelage, became the technological foundation for the thriving rice economy of the southeast coast of the United States in the nineteenth century. Venus Green's study of female black telephone operators in the Bell system links labor history with Bell Telephone's move toward automation at the turn of the last century. In addition, Roger Horowitz integrates class, ethnic, and racial distinctions among women meat packers in the article noted above. Immigrants and African Americans, women with few economic options, work with animal intestines and offal in harrowing conditions beneath the all male killing floors, while younger Caucasian women wrapped bacon for final sale in reasonably comfortable (and publicly visible) rooms. Nina Lerman contrasts curricula for boys and girls in mid-nineteenth-century Philadelphia, looking at schools distinguished

by class and race. Ann Knowles studies the ethnic, class, and racial fault lines of the wartime Confederacy's efforts to manufacture weapons and ammunition.¹⁷

SHOT's move toward a crowded narrative frame is clearly indebted to strong graduate programs which, through reading list requirements, visiting speakers, and the multi-disciplinary composition of faculties, have created environments where cultural, semiotic, and representational theory, as well as sociology, geography, and ethnography complement SHOT's contextual emphasis on the inside of the black box. Most younger historians and many senior figures consider theoretical literacy a necessary condition for competent readings of technological practice.¹⁸

The influence of Donna Haraway in the graduate programs begins to show up in a spate of articles focused on the body. SHOT's approach to the body is distinguished from mainstream representational studies by the field's classic commitment to materiality.¹⁹ Rebecca Herzig sees her subjects, the mostly women and mostly immigrant clients seeking prolonged x-ray treatments for hair removal, as a cultural phenomenon that is unintelligible if the technical capabilities of contemporary x-ray technology are not understood. William Boyd asks, "how science and technology have subordinated the biology of the chicken to the dictates of industrial production." Greg Downey studies the material work that takes place in real locations to physically sustain the internet's primary purpose: actually moving messages from one server to another.²⁰

Although less well known in the larger profession, two other theoretical movements—the systems approach and the Social Construction of Technology—have long been important in SHOT circles. The now-commonplace systems approach is identified principally with Thomas Parke Hughes though it does predate his *Networks of Power* (1983), which remains the locus classicus for understanding technologies as systemic.²¹ Social Construction of Technology is more controversial. Its core thesis—no technological design succeeds simply because it is the best design—defines technological success as contingent and inherently political, an assertion still intensely debated in the field.²² Success requires building coalitions and bonding them to the research and development needed to complete the project ("heterogeneous engineering"). Another pivotal concept, "closure," reveals the Heraclitean propensities of social construction. If a technology cannot be explained as the "best way" to solve a problem, then closure, the moment when some group finalizes the design, becomes crucial for understanding how technologies turn out as they do.²³ Sociologists are not alone in arguing the inherent contingency of successful technological designs. Historian Eric Schatzberg's airframe designers abandoned wood for metal less because of actual efficiencies than because of "assumptions about the superiority of more 'modern' materials (metal) over an older, more traditional one (wood)."²⁴ Contingency matters.

Social construction touches the same nerve among historians of technology as the Science Wars debate has for scientists and historians of science. Critics argue that "closure" depends on more than political prowess, that failures stem more from flawed design than from ineffectual heterogeneous engineering. Charles C. Gillispie and Ken Alder debated Alder's Dexter prize-winning *Engineering the Revolution: Arms and Enlightenment in France, 1763-1815* (1997) at polite but point-blank range. Gillispie objected to Alder's "gloss of extreme politicization" that asks us "to look to politics for an explanation of [the gun's] design and functioning." Alder, a historian, responded with a statement that could serve equally well in sociological circles: "The deep structural level of politics, where the social and ideological patterns of our collective life are played out, necessarily shapes the way material objects and technological knowledge are organized and directed."²⁵ Technology is political.

SHOT's more crowded narrative frame and its deepening methodological interests have stimulated epistemological thinking on several important fronts. Recall that SHOT's original epistemic paradigm emphasized strategies for achieving goals precisely defined in advance.²⁶ By contrast, recent scholarship, a notable amount of it, emphasizes suppleness and the capacity to hold goal definitions open to incongruent and surprising givens in the situation. Two examples show the new profile. Tom Hughes's most recent book, *Rescuing Prometheus* (1998), opens with the spectacular successes of centralized system planners in 1950s weapons projects (Atlas and SAGE) but turns to their equally spectacular failures amidst the messy complexities of Lyndon Johnson's wars on poverty and Vietnam. Hughes concludes by arguing that current projects, such as Boston's Central Artery Project, require a postmodern style of engineering leadership that integrates multiple stakeholders into the design process. In language reminiscent of bricolage theory, Marty Reuss contrasts pure research pushing some state of the art with pragmatic goals at the Waterways Experiment Station (WES) on the Mississippi: "the inability to answer fundamental questions bothers scientists, but WES engineers saw nothing unworthy in aiming for lesser, and more immediate, objectives in the 'real' world of political and economic imperatives. Their results may have been approximate [and] provisional, but . . . these constraints hardly rendered the methodology less valuable." Technological thinkers often favor methods and results that are good enough.²⁷

If historians of technology lagged behind the profession in attention to race and class, SHOT was one of the first historical schools to emphasize locally situated knowledge. SHOT's earliest epistemological consensus, that technological cognition was not reducible to applied science, integrated experimental theory with experience-based knowledge. Sometimes called "skill," sometimes visual knowledge, and sometimes work-based knowledge, the sensual and experiential dimensions of cognition have been important since SHOT's

earliest days.²⁸ Attention to artifacts, the basis for SHOT's pioneering involvement in locally situated epistemology, can also be seen in its long-standing interest in industrial archaeology. Long before SHOT included business historians as active members, industrial archaeologists such as Patrick Malone, Larry Gross, and Robert Gordon argued the key evidentiary role of the artifact in technological history.²⁹

Perhaps nothing shows SHOT's epistemological creativity so much as its remarkable research on precision measurement and standardization, another area where the history of technology leads a trend of growing interest among historians generally. Stimulated in part by SHOT's traditional interest in "The American System of Manufactures" dating to the 1960s and in part by Alder's exemplary study of standardization in Revolutionary France, one can now identify a school of historians of technology who concentrate on the constructed nature of measuring devices that drive standardized systems. Who designs the gauges that serve as seemingly objective arbiters for conflicted social processes such as, to cite topics of recent research: computer system protocols and feedback systems generally, design drawings on the industrial shop floor, and diverse precision measuring devices designed to adjudicate alcohol content in British spirits (determinative of the infamous excise taxes at the turn of the nineteenth century), appropriate "wetness" for concrete, the carat value of gold in jewelry, toxicity levels in industrial solvents? More and more historians of technology make it their business to explore the politics and techniques of precision, a contingent and turbulent research site of immense importance for understanding the modern and postmodern worlds. Here of course, understanding the inside of the black box is essential.³⁰

My emphasis on a more crowded narrative frame and SHOT's methodological turn and epistemological creativity does not mean that SHOT's traditional stories of technological creativity have gone out of favor. Projects exploring sophisticated technological achievement remain a staple and range across the geographical and chronological spectrum. The most coherent cluster concentrates on what have come to be known as Large Technological Systems (LTS): Cold War weapons (Atlas, Minuteman, Apollo), NASA, satellites, laboratories dedicated to nuclear weapons, high energy physics, and astronomy. So complex are the technologies that drive these projects that they required new managerial methods such as systems management and systems analysis that evolved from World War II's Operations Research.³¹ The computerization of computerization generally, helps explain SHOT's strength in computer history. While much computer history is so recent as to defy thorough interpretation, monographs by Janet Abatte, Paul Ceruzzi, Martin Campbell-Kelly and William Aspray, Arthur L. Norberg and Judy E. O'Neill,

and Alex Roland have already laid an impressive foundation for this flourishing focal area clearly still in its early stages.³²

The theoretical fluency of much recent contextual history is revealing and suggests that it would be over simple to separate SHOT scholars into old school and new. The older contextual tradition, focused on technological achievement, has clearly been influenced by the newer emphases on contingency and vice versa. On the one hand, "new" research projects (cultural studies, gender, race, non-western perspectives), studies of user redefinition of technologies) almost always manifest SHOT's enduring commitment to getting the technology right. On the other hand, many recent studies of what look like tried and true achievement studies are infused with the political and cultural at a level not often found before 1990.³³

The particular expertise and collective energy that has come to maturity in SHOT over the past two decades has generated a widely held conviction among historians of technology that when the insides of black boxes are interrogated for what they reveal of their host society's biases, commitments, and cultural subtleties, the history of technology can bring fresh insight to current historical questions. It is not surprising, then, that SHOT scholars have become more active in the larger discipline and write for broader audiences than before. Three ventures show something of the energy behind this outreach. SHOT's joint booklet series with the AHA has already been mentioned. Four textbooks in the history of American technology have appeared in the last five years and one major American history text commissioned explicitly to integrate the history of science and technology into mainstream American narratives is nearing completion.³⁴ SHOT's newest book prize, The Sally Hacker Award, goes to the best book aimed at a popular audience.³⁵

The ferment in the history of technology shows itself, finally, in recent calls by senior scholars for SHOT to address the perennial historical questions of narrative and agency as these issues are influenced by recent methodological thinking. Philip Scranton has recently argued that the field creates narratives where agency is understood to be institutional as well as individual and where agency occurs after a technology enters the world of ordinary use. He argues for integrating SHOT's core areas of expertise, in particular contextual history and social construction, with the insights emerging from anthropology, ethnomethodology, and organizational sociology.³⁶ SHOT's persistent criticism of the Cold War master narrative and its insider talk about the tendency of other historians to misread the insides of black boxes may have become almost passé. Many historians of technology now find refutation of the master narrative with case studies of messy complexity no longer an adequate rationale for publication. Which technological narratives are worth telling? How do we make sense of technologies, and the institutions and

individuals who maintain them and whose lives are shaped by them, as centers of agency? What to make of the myriad technologies so intimately involved with the bodies of humans and animals and plants? How to understand the not-so-latent colonialism at work in the technological foundations of the global economy? What are the technological implications of the staying power of local and indigenous cultures, especially in non-Western "nations" after the end of the Cold War, in the face of the modern state's drive for order?³⁷

SHOT's move toward a crowded narrative frame invites historians of technology to step out onto the visible stage of their own writings. If technological narratives can include wage workers, consumers, non-Westerners, women, and minorities, surely there might be room for the historian author as well. I find, however, at least in editing T&C, that many historians are reluctant to publicly visit the passion that motivated their decisions about research subject matter or about the questions that lie beneath the argument they choose to explore. Still, the ferment within SHOT may be signaling change here too.

The urgency that many SHOT historians bring to the challenges of their craft—elusive technological agency and legitimate voices in technological narratives—may explain Rosalind Williams's recent essay in T&C. Her just-completed five years as undergraduate dean at MIT reveal dramatic changes in the MIT educational culture and, argues Williams, challenge historians of technology to change their ways. Williams calls for a restoration of passion in language that aptly depicts SHOT at a moment of transformation:

In the history of technology, passion serves an epistemological purpose. Strong emotion acts as a probe. It takes historians into a subject and motivates them to keep digging further. Passion has been out of style, in the cool intellectual twilight of postmodernity, where the prevailing mood is to dissect with irony and the prevailing fear is to make naive claims. Historians need to risk being uncool.³⁸

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1. Abbott Payson Usher's *History of Mechanical Inventions* (1929) was considered a model of scholarship for the founding generation of SHOT as indicated by naming *Technology and Culture's* best article award the Usher Prize. Three multi-volume series, all published about the time of SHOT's beginning, represented the high end of internalist historical practice: Charles Singer, E.J. Holmyard, A. R. Hall, and Trevor I. Williams, eds., *A History of Technology*, 5 vols. (1954–58); Maurice Daumas, ed., *Histoire Générale des Techniques*, 3 vols. (1964 ff); A. A. Zvorikine et al., *Geschichte der Technik*, 2 vols. (1962; German trans., 1964).

Mel Kranzberg took on the lion's share of the work involved in launching SHOT. He served both as secretary and editor-in-chief of *Technology and Culture* for SHOT's first sixteen years and continued as editor until 1981. For recent accounts of SHOT's origins see Bruce E. Seely, "SHOT, the History of Technology, and Engineering Education," *Technology and Culture* (hereafter T&C) (October 1995); and Robert C. Post, "A Very Special Relationship: SHOT and the National Museum of History and Technology," T&C (July 2001).

2. Mumford, *Technics and Civilization* (1934) and *Geolon Mechanization Takes Command: A Contribution to Anonymous History* (1948). Mumford actively supported Kranzberg's early editorial efforts and published 4 articles between 1961 and 1966 including the highly regarded "Authoritarian and Democratic Technics" T&C (Winter 1964). Louis C. Hunter, with the assistance of Beatrice Jones Hunter, *Steamboats on the Western Rivers: An Economic and Technological History* (1949); Irving Brinton Holley, *Ideas and Weapons: Exploitation of the Aerial Weapon by the United States during World War I: A Study in the Relationship of Technological Advance, Military Doctrine, and the Development of Weapons* (1953).

3. For detailed arguments behind these assertions of contextualism, see my *Technology's Storytellers: Revenanting the Humm Fabric* (1985), esp. Chap. 5.

4. Some of the books on most SHOT members 5-foot shelf include: Hugh G. J. Aitken *Taylorism at the Watertown Arsenal: Scientific Management in Action, 1908-1915* (1960) and *Syntax and Spark: The Origins of Radio* (1976); Edward W. Constant II *The Origins of the Turbojet Revolution* (1980); Thomas Parke Hughes, *Elmer Sperry, Inventor and Engineer* (1971); Reese V. Jenkins *Images and Enterprise: Technology and the American Photographic Industry 1829-1925* (1975); Judith A. McGaw, *Most Wonderful Machine: Mechanization and Social Change in Berkshire Paper Making, 1801-1885* (1987); David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (1977); Bruce Sinclair, *Philadelphia's Philosopher-Mechanics: A History of the Franklin Institute* (1974).

By "interrogating clean-line narratives," I mean something close to Michael Kammen's "problem-oriented" scholarship. See his "An Americanist's Reprise: The Pervasive Role of *Historic Probleme* in Historical Scholarship Concerning the United States Since the 1960s," *Reviews in American History* (March 1998):1-25.

5. Many SHOT scholars consider Donald Mackenzie's *Inventing Accuracy: An Historical Sociology of Nuclear Missile Guidance* (1990) paradigmatic of technologically sophisticated interrogation of design contingencies. Mackenzie is said to have deliberately chosen one of the blackest boxes of all, intercontinental ballistic guidance systems, to demonstrate the influence of ideology and world view (here the U.S. and Soviet defense establishments) on contingent technical designs.

6. The Dexter and Usher prizes (best book and best article in T&C respectively) often reward technological fluency and with few exceptions remain less visible outside SHOT. For prize citations see the July issue of *Technology and Culture* annually (beginning in 2002, see the January issue). Henry Lowood compiles a more comprehensive look at SHOT's definition of the universe of relevant scholarship as editor of T&C's annual bibliography, published as a separate fifth number.

7. Due by the end of 2002 are Rudi Volti, *Technology Transfer and East Asian Economic Transformation*; Philip Scranton and Roger Horowitz, *Sites of Labor: Work and Technology in American History*; Barton C. Hacker, *Military Technology, Military Institutions, and World History*. Three other proposals (on material culture, environmental history, and medieval technology) are pending.

8. These comments understate the overlap between business history and the history of technology. Scranton exemplifies the mutuality most completely. He integrates business history with the history of technology in several books including: *Proprietary Capitalism: the Textile Manufacturing at Philadelphia, 1800-1885* (1983); *Figural Typology: Production, Markets, and Power in Philadelphia Textiles, 1885-1941* (1989); *Endless Novelty: Speciality Production and American Industrialization, 1865-1925* (1997). Scranton serves as book review editor for the Business History Conference's new journal *Enterprise and Society* and as Advisory Editor at T&C. He currently sits on SHOT's Executive Council and is president-elect of the Business History Conference. David Hounshell wrote the Dexter Prize-winning *From the American System to Mass Production, 1800-1937: The Development of Manufacturing Technology in the*

United States (1984). He serves as president-elect of SHOT and has long been a leading scholar in business history.

Pamela Walker Laird is both a trustee of the Business History Conference and a member of SHOT's Executive Council; see her *Advertising Progress: American Business and the Rise of Consumer Marketing* (1998). For other scholarship integrating history of technology and business history, see Regina Blaszczyk, *Imagining Consumers: Design and Innovation from Wegwood to Corning* (2000); Colleen Dunlavy, *Politics and Industrialization: Early Railroads in the United States and Prussia* (1994); Richard John, *Spreading the News: The American Postal System from Franklin to Morse* (1995).

9. Iarr and Stine, "At the Intersection of Histories: Technology and the Environment," T&C (October 1998). Recent examples of environmental history /history of technology include: Hugh Gorman, *Redefining Efficiency: Pollution Concerns, Regulatory Mechanism, and Technological Change in the U.S. Petroleum Industry* (2001); and Edmund Russell, *War and Nature: Fighting Humans and Insects with Chemicals from World War I to Silent Spring* (2001). SHOT regular Martin V. Melosi won the George Perkins Marsh prize for best book of environmental history in 2001 (*The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present* [2000]).

10. Fitzgerald, *The Business of Breeding: Hybrid Corn in Illinois, 1890-1940* (1990) and Kline *Consumers in the Country: Technology and Social Change in Rural America* (2000). For recent work by younger scholars, see Suzanne Moon, "Takedoff or Self Sufficiency? Ideologies of Development in Indonesia, 1957-1961" T&C (April 1998) and William Boyd, "Making Meat: Science, Technology, and American Poultry Production," T&C (October 2001).

11. Two articles by senior scholars initially raised the question. In addition to Cowan, "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, ed. Wiebe Bijker, Thomas P. Hughes and Trevor Pinch (1989), see Judith A. McGaw's oft-cited "No Passive Victims, No Separate Spheres: A Feminist Perspective on Technology's History" in *In Context: History and the History of Technology: Essays in Honor of Melvin Kranzberg*, ed. Stephen H. Cutcliffe and Robert C. Post (1989): 172-91.

12. Ronald R. Kline and Trevor J. Pinch, "Users as Agents of Technological Change: The Social Construction of the Automobile in the Rural United States," T&C (October 1996). Kline and Pinch are explicit about their methodological intentions. "In this essay, we . . . argue that users of technology acted as agents of technological change. By treating farm people as active participants in the social construction of the automobile, we seek to extend recent work in the history of technology that shifts the field's traditional focus from the 'producers' of technology (e.g., inventors, engineers, and manufacturers) to the 'users' of technology (e.g., laborers, factory owners, home-workers, and consumers)" (p. 764).

Other examples of consumers redefining technologies include: Carolyn M. Goldstein, "From Service to Sales: Home Economics in Light and Power, 1920-1940," T&C (January 1997); and Wendy Gamber, "Reduced to Science: Gender, Technology, and Power in the American Dressmaking Trade, 1860-1910" (T&C 1995).

13. Women in Technological History (WITTH) has become SHOT's most active special interest group. It was founded in 1976 after SHOT's annual meeting where Martha Moore Trescott organized and moderated (with Ruth Schwartz Cowan) the Society's first session devoted entirely to women and technology. Proceedings of the session formed the basis for Martha Moore Trescott, ed., *Dynamics and Virgins Revisited* (1979). For another collection of early gender and technology work, see Joan Rothschild, ed., *Machine ex Dar: Feminist Perspectives on Technology* (1983).

14. Only 4.6 percent of T&C authors before 1980 were women; in the past eight years 25 percent are women. For women's and gender history, SHOT's most substantive cluster appears in T&C's Special Issue: Gender Analysis and the History of Technology (January 1997).

15. Parr, "What Makes Washday Less Blue? Gender Nation and Technology: Choice in Postwar Canada," T&C (January 1997); Horowitz, "Where Men Will Not Work: Gender, Power, Space, and the Sexual Division of Labor in America's Meatpacking Industry," T&C (January 1997); Lipartito "When Women Were Switches: Technology, Work, and Gender in

the Telephone Industry 1890-1920." *American Historical Review* 99 (1994). For a similar argument, about early computers, see Jennifer Light, "When Computers Were Women," T&C (July 1999).

16. Moon, "Takeoff or Self-Sufficiency?"

17. Carney, *Black Rice: The African Origins of Rice Cultivation in the Americas* (2001); Green, *Race on the Line: Gender, Labor, and Technology in the Bell System, 1880-1980* (2001). See also Horowitz, "Where Men Will Not Work"; Leman, "Preparing for the Duties and Practical Business of Life: Technological Knowledge and Social Structure in Mid-19th-Century Philadelphia," T&C (January 1997); Knowles, "Labor, Race, and Technology in the Centennial Iron Industry," T&C (January 2001).

18. See, for example, Kevin Borg's application of Anthony Giddens in "The 'Chauffeur Problem' in the Early Auto Era: Structuration Theory and the Users of Technology," T&C (October 1999).

19. Donna Haraway, in her landmark book, *Simians, Cyborgs, and Women* (1991) and subsequent work chooses to occupy a place of irresolvable tension—is there a trans-cultural moral ground from which to interrogate the locally situated exercise of knowledge and power. Her intentional ambiguity about objectivity has caught the attention of younger SHOT scholars perhaps because her work touches SHOT's own tension between technologically objective practice and locally situated experiential skill. For an example of mainstream representational studies, see Ludmilla Jordanova and Charles Saumarez Smith, *Defining Features: Scientific and Medical Portraits, 1660-2000* (2000).

20. Rebecca Herzig, "Removing Roots: North American Hiroshima Maidens' and the X Ray," T&C (October 1999); William Boyd, "Making Meat"; Greg Downey, "Virtual Webs, Physical Technologies, and Hidden Workers: The Spaces of Labor in Information Internetworks," T&C (April 2001). See also Carolyn Thomas de la Peña "Recharging at the Fordyce: Confronting the Machine and Nature in the Modern Bath," T&C (October 1999).

21. Hughes was hardly alone in finding systems thinking attractive in the 1970s. For an overview of commonplace systems language before 1980, see *Technology's Storytellers*, Chap. 2, pp. 69-82.

22. European pioneers of the social construction school have close ties with their more science-oriented colleagues such as Bruno Latour and Harry Collins. The acronym SCOT has, with some imprecision, evolved into a generic title for social construction, actor-network, and related sociological theories. For an introduction, see W. E. Bijker and J. Law, eds. *Shaping technology/building society: Studies in sociotechnical change* (1992). On the intellectual complementarity of social construction and the history of technology, see my "Problematic Stimulation: Historians and Sociologists Constructing Technology Studies" in *Research in Philosophy and Technology*, Vol. 15 (1995): 93-102.

23. Sociologists, it should be noted, have begun to pay attention to technologies after closure. Sociological studies have begun to focus on the power of users to redefine the meaning of technologies once they leave the factory. See Kline and Pinch, "Users as Agents of Technological Change."

24. Schatzberg, "Ideology and Technical Choice: The Decline of the Wooden Airplane in the United States, 1920-1945," T&C (January 1994). Quoted text appears in the Usher Prize citation T&C (July 2998): 514. On the study of technological ideology, see also Joseph J. Corn, *The Winged Gospel: America's Romance with Aviation, 1900-1950* (1983). The influence of ideology on technological design is also a central concern for Mackenzie's *Inventing Aircraft*.

25. Exchange: Charles C. Gillespie and Ken Alder, *Engineering the Revolution*, T&C (October 1998): 738, 743.

26. Many consider Walter G. Vincenti's *What Engineers Know and How They Know It* (Baltimore: 1990) the high water mark for the epistemology of goal-directed technological thinking.

27. Martin Reuss, "The Art of Scientific Precision: River Research in the United States Army Corps of Engineers to 1945," T&C (April 1999): 323. The parallel to *bridgeland* theory of knowledge was explicitly linked to SHOT in Robert C. Post's *High Performance: The Culture*

and *Technology of Ding Racing 1950-1990* (1996) and in ethnographer Douglas Harper's *Working Knowledge: Skill and Community in a Small Shop* (1987).

28. Two of SHOT's founders wrote books that remain influential to the present: Eugene Ferguson, *Engineering and the Mind's Eye* (1992); and Brooke Hindle, *Emulation and Invention* (1981). Both study the sensual and visual in technological creativity. On SHOT's early work integrating theoretical and experiential thinking, see *Storytellers*, Chap. 3.

29. For an exemplary model of industrial archeology scholarship, see Malone and Gordon eds. *The Texture of Industry: An Archaeological View of the Industrialization of North America* (1994). For another collection of substantive scholarship with a material culture bent, see Judith A. McGaw, ed., *Early American Technology: Making and Doing Things from the Colonial Era to 1850* (1994).

30. Within SHOT the literature begins to be vast: Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenge of Change* (1977); Hounshell *From the American System to Mass Production*; Janet Abate and Amy Stalon, "The Hidden Lives of Standards: Technical Prescriptions and the Transformation of Work in America," Michael Allen and Gabriel Hecht, eds., in *Technologies of Power* (2002); Amy Stalon *Reinforced Concrete and the Modernization of American Building* (2001); William Ashworth, "Between the Trader and the Public: Defining Production and Measures in Eighteenth-Century Britain," T&C (January 2001); Dario Gaggio, "Negotiating the 'Gold Standard': Quantification, Trust, and Informality in the Italian Gold Jewelry Industry," T&C (April 2002); Geoffrey C. Bowker, *Science on the Run: Information Management and Industrial Geophysics at Schlumberger, 1920-1940* (1994); and Ted Porter *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (1995).

31. For something of a who's who of current research in the large technical system area, see Agatha C. Hughes and Thomas P. Hughes, eds., *Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After* (2000). The festschrift for Tom and Agatha Hughes *Technologies of Power* blends systems thinking with the theoretical fluency now typical of younger scholars.

32. Abbate, *Inventing the Internet* (1999); Campbell-Kelly and Aspray, *Computer: A History of the Information Machine* (1996); Ceruzzi, *A History of Modern Computing* (1998); Norberg and O'Neill, *Transforming Computer Technology: Information Processing for the Pentagon, 1962-1986* (1996); Roland with Philip Shiman, *Strategic Computing: DARPA and the Quest for Machine Intelligence, 1983-1993* (2002).

33. Jack Brown blends old and new scholarship in "Design Plans, Working Drawings, National Styles: Engineering Practice in Great Britain and the United States, 1775-1945," T&C (April 2000). For further research on the representational work done by technological drawings, see David McGee, "From Craftsmanship to Draftsmanship: Naval Architecture and the Three Traditions of Early Modern Design," T&C (April 1999).

34. Alan I. Marcus and Howard P. Segal, *Technology in America: A Brief History* (1989); Carroll W. Pursell, *The Machine in America: A Social History of Technology* (1995); Cowan, *A Social History of American Technology* (1997) and Gary S. Cross and Rick Szostak, *Technology and American Society: A History* (1995). For a review of all four, see David E. Nye, "A Moment of Synthesis: Recent Textbooks in the History of Technology," T&C (April 1998). The nearly complete U.S. history text is being written by Merritt Roe Smith, Pauline Maier, Dan Keyes, and Alex Keyssar.

35. The first Sally Hacker Prize went to Michael Riordan and Lillian Hoddeson for *Crystal Fire: The Birth of the Information Age* (1997).

36. Scranton, "Using and Producing Technologies: SCOT and What?," paper at the 2000 SHOT annual meeting in Munich.

37. On the issue of nation state and local culture, an area under-represented in SHOT scholarship to date, see James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (1998).

38. Williams, "All That is Solid Melts into Air: Historians of Technology in the Information Revolution," T&C (October 2000), 667.