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Barton C. Hacker

Gunpowder began the military revolution that molded the modern world. Relatively narrow technical changes in weapons and tactics on early modern European battlefields set in train the transformation of almost every aspect of Western civilization, argued Michael Roberts in 1956.¹ Widely discussed and critically challenged, his version of the precise nature and timing of change on the equation's military side now commands only qualified respect.² But the other side of the equation, Roberts's claim of great social consequences flowing from changing military technique, remains substantially intact. It retains enough plausibility, in fact, to suggest thinking about similar processes in other eras.

Dr. Hacker is the historian at Lawrence Livermore National Laboratory. Earlier versions of this article were presented at meetings of the Pacific Sociological Association, Albuquerque, N.M., 1985; International Congress of History of Science, Berkeley, Calif., 1985; Symposium of the International Committee for the History of Technology, Dresden, 1986; Inter-University Centre of Postgraduate Studies, Dubrovnik, 1987; Columbia History of Science Society, Friday Harbor, Wash., 1987; and Society for the History of Technology, Raleigh, N.C., 1987. The author wishes to thank the several friendly critics who helped him reshape and sharpen his argument.


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Military technological change of vast scope disturbed the 19th century, beginning with small arms and guns vastly quicker-firing and longer-ranged than the weapons they displaced. Other changes followed ever more rapidly, spreading through the military system, then throughout society. Ultimately, the result was a new social, political, and economic order. Like its early modern predecessor, this 19th-century transformation deserves the label military revolution because its consequences far transcended strictly military concerns. The 20th-century industrial state is no less the product of a 19th-century military-technological revolution than was the 18th-century nation-state of the classic military revolution Roberts spotlighted.

The present undertaking is more survey than analysis, the subject being far too complex for a brief essay. Accordingly, I address only certain aspects of the 19th-century military-technological revolution, its 18th-century roots, and its 20th-century fruits. Pragmatism largely dictates my focus on the United States—the needed material is more readily available in my provincial outpost—though I do include comparative remarks where they seem appropriate. Despite such self-imposed limits, this essay may still prove helpful to readers seeking an entry to published work on certain relevant topics. It may also serve as a sounding board for several useful themes, chief among them the interaction between military and other social institutions. Only by understanding such interactions may we begin to explain the course and outcome of 19th-century military technological change.

My touchstone is the spread of a novel usage to replace, or at least augment, what had normally in the past been called "the art of war." During the 19th century, "military science" or "military art and science" largely supplanted the older term. Methods of educating officers and training soldiers altered sharply. These changes had important implications for technical education and the organization of work outside as well as within the armed forces. Corporate management, patterns of professionalization in related fields, the very process of industrialization drew on military models and batten on military funding. But traffic flowed both ways. Military technology and organization also reflected outside changes. Becoming visible as well were early signs of the complementary civilianization of the armed forces and militarization of society that so marks the 20th century. Although the nature of military expertise mattered, just as did the nature of special competence in other fields, military practice and values played a special role in furthering the process of social change that created the modern world.
Military Education and Professionalization

Military institutions changed dramatically in the 19th century, driven in large part by technological innovation. Between 1815 and 1914, soldiers traded smoothbores for rifles and grapeshot for shrapnel. Doffing gaudy colors in favor of field gray or khaki, they left firing lines and maneuver for ground cover and trenches. Repeating rifles, smokeless powder, quick-firing long-range field artillery, and machine guns multiplied firepower and expanded the killing zone. Runners gave way to telegraph and wireless, muscle to steam and petrol. Staffs burgeoned to direct vast armies as nations prepared to put millions of men under arms. Virtually every aspect of military life was altered if not transformed, and the rate of change seemed always to increase.3

Innovations so radical scarcely passed unnoticed. Novel weapons figured prominently, for instance, in popular turn-of-the-century compendia on the progress of invention.4 Yet assessing their import surpassed most contemporary imaginations, baffling military and civilian minds alike.5 Indeed, many have blamed the catastrophe of World War I on European armies blind to the demands of a swiftly changing technology, though that judgment may be too harsh.6


Innovations in 19th-century military technology mostly came from nonmilitary sources. That made the flood of new or improved arms hard to control or direct. Military planners did not so much ignore the problems as misjudge their magnitude.7

Certainly, some observers outside as well as within the armed forces foresaw what technological innovation might mean at several levels of military concern. As early as the 1860s, for instance, Frederick Engels had published shrewd comments on the potential tactical implications of rifled cannon and small arms.8 By century's end, the outline of still wider ramifications had emerged. Inevitably, change demanded and promoted more change, concluded Cornelis de Witt Willcox, a career officer and turn-of-the-century instructor at West Point: organizational innovations like the general staff allowed growing armies to be controlled; production innovations like interchangeable parts manufacturing allowed them to be equipped; communications innovations like railroad and telegraph allowed them to be supplied and directed.9 None of this need be construed as technological determinism: new weapons are products as well as causes of social change.10 Further-


more, as John Lynn notes, institutions and ideas are just as much tools of war as hardware.\textsuperscript{11}

Military education was one of the areas transformed during the 19th century, in both subject and method. Soldiering had begun as a craft. Like all crafts, it passed such skills as weapon-handling to novice practitioners through the example of elders and on-the-job training. During the early modern military revolution, these "skills were divided, simplified, rationalized, and systematized to be taught routinely, quickly, and efficiently."\textsuperscript{12} Standardized techniques for imparting basic skills spread to all armed forces.\textsuperscript{13} Proving widely adaptable, they could be extended to less obviously military areas within armies, training cooks, for instance, or radio repairers.\textsuperscript{14} Nor were they limited to strictly military contexts. Technical training of many kinds grew from military roots.\textsuperscript{15} Traces of that origin survive, and to this


day military training continues to transfer skills to civil society. In due course, the techniques devised for military ends proved useful for still other purposes. Among them, one of the earliest and most persistent involved the armed forces in modernization, teaching recruits the basic skills of modern life.

Apprenticeship or on-the-job training remained the rule for those destined by birth to command long after that had ceased to be true for the lower ranks or technical officers. To officers in the combat arms, infantry and cavalry above all, war remained an art, proficiency achieved only by practice. But the 18th century saw such views challenged, if not overthrown. Reformers conceived the possibility of a military science allied to improved formal education for officers.

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This, perhaps as much as any factor, accounts for the founding and spread of military schools and academies from the mid-18th century onward. During the following century, formal schooling became part of every officer's career.

By the later 19th century, the concept of military science had become a commonplace. In 1878 a professor of military engineering, Colonel J. B. Wheeler, drew the distinction between art and science for cadets at West Point: principles, analyses, rules "all these belong to the 'Science of War.' The application of these great principles and rules belongs to the 'Art of War.'"23 Another officer, Captain Henry McCalfe, expressed the meaning of science and art for many 19th-century thinkers in his classic 1885 management treatise. Science and art were allied but distinct. "Art seeks to produce certain effects, Science . . . [to investigate] the causes of these effects." Regardless of the art, he continued, "there always seems room for a corresponding science, collecting and classifying the records of the past so that the

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future operations of the art may be more effective.” Arsenal administration, Metcalfe’s specialty, provided a concrete example: It “is in great measure an art, and depends upon the application to a great variety of cases of certain principles, which, taken together, make up . . . the science of administration.”

Pursuing the art of war could now begin from a solid base, the underlying principles codified as military science to be taught in the classroom. Military science gained support as an attempt to abstract and systematize a body of esoteric knowledge suited to indoctrinating the 19th century’s growing numbers of nontraditional candidates for officer status. Like other professionalizing fields, notably engineering, the armed forces of Europe and America faced an influx of middle-class men seeking careers. Presumably lacking the genetic predisposition of their aristocratic comrades, they needed concrete and readily reproducible examples: schematic maps all could see, war games all could play, rules all could memorize. None of these teaching aids were new, but their use burgeoned during the 19th century and became a staple of the 20th.

Paradoxically, military education also grew more complex and sophisticated even as some of its subjects became oversimplified and standardized. The reoriented curricula of older schools in Europe and the United States added courses in strategy and policy to the familiar tactics and technology. At new schools founded for that very purpose, postgraduate military training became first available, then a


required prelude to higher command. Strategic and other higher military studies in the United States proliferated in the context of turn-of-the-century reform movements that affected military as well as civil society. In the 20th century such studies have become a central feature of advanced military education. All such courses and programs pointed toward professionalization, with officers educated to wield sanctioned violence responsibly.


Though probably not the cause, profound and rapid social change nonetheless strongly colored the professionalization of armed forces, like other corporate groups during the 19th century. Radical change justified concomitant claims to special expertise. Elaborating esoteric bodies of knowledge and technique then allowed practitioners to limit access to the field. Codified and abstracted knowledge channeled the entry of candidates properly trained and indoctrinated. During the 19th century many fields shifted from apprentice and other on-the-job methods of training new members toward school or other more formal and abstract means of transmitting and perpetuating professional culture. 31 But special knowledge, special skill, and restricted numbers only counted if a group could claim to serve higher social purposes. Promoting that claim was the key to professionalization. Only when society accepted professional training and competence as socially needed and wanted could the newly defined corporate group claim special social privilege, which was, of course, the whole point. 32

Professionalizing groups all sought to make special schooling a prerequisite for professional entry, bureaucratic office, or masculine privilege. Armed forces, however, were not merely one more instance of a widespread 19th-century phenomenon. Military institutions regularly pioneered the techniques of discipline, order, and privilege that other social institutions adopted. 33 At one level, the support for a distinctive military science reflected concerns for institutional survival during a time of flux in technique and organization. 34 More generally,


however, it showed how institutions might respond to rapid social change and became a model of such response, often implicit but sometimes, as in engineering, overt. Sc. Scientific management, medical science, social science, and a host of other 19th-century coinages, even science proper, all testify to the widely perceived value of coping with change by turning lore into systematic knowledge. We need not ignore the practical uses and social value of knowledge so arranged to see that it benefits its possessors in more ways than one.

**Engineering Education and Management**

Engineering education, like engineering itself, had military roots. The very term “civil engineer” appeared in the 18th century to name


a new kind of practitioner: one who engineered something besides fortifications or weapons (though roads, bridges, railways, and other state-sponsored civil projects may themselves betray more than a trace of military motive). Higher engineering education everywhere began in military schools. Scarcely had the United States achieved independence when George Washington urged the establishment of "Academies, one or more for the Instruction of the Art Military; particularly those Branches of it which respect Engineering and Artillery, which are highly essential, and the knowledge of which, is most difficult to obtain." Although other motives played a part, the 1802 founding of the United States Military Academy at West Point owed much to such concerns.

Schools like West Point became and remained the chief way to recruit and train technical officers: engineers and gunners early,


other specialties in later years. And, like vocational training techniques pioneered for troops, educational methods devised for technical officers showed great adaptability. Graduates of West Point joined, sometimes founded, civil engineering programs and schools elsewhere. Expertise derived from military technical training proved to have many uses, outside the army as well as within. Men trained at West Point explored and mapped westward across the continent. They built forts, but they also built the network of roads and waterways that began to crisscross the United States in the early 19th century, and then they built railroads.

In Europe, especially in France, the line between military and civil engineers often remained indistinct. Engineering schools routinely


provided the disciplined training required for those who would administer the state.\textsuperscript{48} They also trained the indispensable managers for corporate enterprise.\textsuperscript{49} The matter was not so clear in the United States. In his influential study of the 19th-century rise of modern corporations, Alfred Chandler acknowledges the West Point training of many of those who helped transform American economic life. Nonetheless, he explicitly rejects any direct military influence because few of them had much of an active army career.\textsuperscript{50} By century's end, in fact, influence seemed to run the other way. Lieutenant Colonel William H. Carter, a leader in the fight for a general staff in the U.S. Army, could liken military leaders to railroad directors—"groups of men whose principal work was to observe rival lines, to consider state and local laws, and to prepare their systems to derive all possible advantage from future growth."\textsuperscript{51} But this may reflect interaction and merged viewpoints more than cause and effect.

Several lines of evidence suggest that, even in the United States, military models played a larger part in molding the corporate order


\textsuperscript{51}As quoted in Karsten, "Armed Progressives" (n. 28 above), p. 251.
than Chandler allows or Carter implied. Management by staff and line, a key feature of the rising corporation, had self-evident military sources. But that was not all. Engineers in the United States not only helped devise corporate organization but also came to constitute the largest share of middle management. Furthermore, they instructed their civilian counterparts, and not only by helping to found colleges of engineering. The first book on factory management ever published in the United States was the handiwork of a career army officer who managed an arsenal; he addressed his 1885 classic less to fellow officers than to his managerial counterparts.

Military concerns and money, sometimes direct, sometimes funneled through corporate intermediaries, affected higher education in many ways. Military training on campus dated to the Morrill Act of 1862 but became institutionalized in the form of the Reserve Officer Training Corps (ROTC) only in 1916. Engineers figured prominently among supporters of this contested institution. During the era of World War I, American schools of engineering used military models in organizing research laboratories, adapted their curricula to meet military demands, and borrowed military test methods to evaluate


their students. Consequences might be as subtle as those entailed in using personality tests and job specifications created for military purposes during the war. At the other extreme lay the overt effects of research channeled by military funding. By whatever paths, military values of order, discipline, and hierarchy pervaded engineering.

American universities, like much of American society, for the most part welcomed such values in the later 19th and earlier 20th centuries. After he became the first head of the University of Illinois in 1867, John M. Gregory regularly cited the value of "military order and daily chapel . . . for discipline, character development, and the general tone of the campus." When the United States entered World War I, colleges became enthusiastic centers for military training and education. They were scarcely less eager during peacetime. Youthful


Dooley, Final Report of the National Army Training Detachments (n. 14 above); Parke Rexford Kolbe, The Colleges in War Time and After: A Contemporary Account of the Effect of
Americans would also come to enjoy such virtues, which spread to secondary, even primary, schools via Junior ROTC and vocational education.62 To many Americans, that seemed both worthwhile and desirable. Discipline derived from military training in public schools "early impressed upon the mind of the pupil," argued an American observer in 1903, "the first lessons of civil government and respect for law."63 Such lessons held no less value for adults.64 Militarism could be one side of the coin, but civic virtue and patriotism might be the other.65 In many respects, a similar pattern prevailed in England.66 It was, of course, even more widespread on the Continent.67

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Industrialization itself owed no small debt to military interests. From the late-18th- and early-19th-century development of interchangeable parts manufacturing in navy shipyards and army arsenals to the late-20th-century U.S. Air Force sponsorship of automated machine tool development, key aspects of industrial technology emerged from military settings.\(^6^6\) But military example may have been even more important. Discipline was the key, argued Max Weber, military practice its inspiration. He thought it self-evident that "military discipline is the ideal model for the modern capitalist factory."\(^6^9\) Lewis Mumford put the point more emphatically a few years later: "The regimentation and mass-production of soldiers, to the end of turning out a cheap, standardized, and replaceable product, was the great contribution of the military mind to the machine process."\(^7^0\)

Even antimilitaristic socialists grasped the merits of military organization. In 1832 the Saint-Simonian Michel Chevalier proposed making the army a school of arts and crafts, training youth to produce rather than destroy.\(^7^1\) Expounding Charles Fourier's system in 1846, Victor Considérant waxed eloquent over the prospects of phalansterial industrial armies "to carry out, as if by magic, vast projects of general utility requiring legions of workers."\(^7^2\) Military regimentation

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\(^6^6\)Mayr and Post, eds., Yankee Enterprise (n. 50 above); Smith, Military Enterprise and Technological Change (n. 53 above); David F. Noble, Forges of Production: A Social History of Machine Tool Automation (New York, 1984).


did become a model for rationalized production, though not as utopian visionaries might have wished. Entrepreneurs and captains of industry found much to admire, and to adopt, in the regimentation and redivision of labor imposed on modernizing armies. When Marx and Engels described the labor process in capitalist factories, they turned naturally to military metaphor: "Masses of labourers, crowded into the factory, are organized like soldiers."\(^{73}\)

Sociologist Jacques van Doorn has lately sought to link military to industrial revolution through the motives shared by a major architect of each.\(^{74}\) Maurice of Nassau became a key figure in the military revolution when he restored drill to armies in the late 16th century.\(^{75}\) Frederick W. Taylor reshaped industrialism when he devised scientific management in the late 19th and early 20th centuries.\(^{76}\) Parallels between Maurice and Taylor were "not fortuitous," argues van Doorn. They faced the same problem: welding a "goal-attainment organization" from a mass of socially isolated, ill-trained, and poorly motivated proletarians. Sharing a mechanistic image of human behavior, they found their common answer in regimented action.\(^{77}\) Military and industrial revolution alike "made their spectacular leap forward," van Doorn adds, "by a more efficient and concentrated organization of human effort, not by mechanization."\(^{78}\) And for Taylor, at least, it was a two-way street. Military models influenced his reforms, and Taylorism found a receptive military audience.\(^{79}\)


\(^{77}\)Van Doorn, The Soldier and Social Change, p. 15.

\(^{78}\)Ibid., p. 17.

Military Institutions as Social Institutions

The rise of the modern industrial state in the 19th and 20th centuries is but the latest manifestation of the ancient interplay between military and other social institutions. Military institutions are the patterned social relationships between individuals and groups that organize and control the wielding of coercive force by one segment of society against others, internal or external. Obviously, this definition includes armies, perhaps not so obviously, navies and air forces, perhaps still less obviously, police. Until the 19th century in Europe, domestic order relied on amateur or part-time constabularies, with the army on tap if matters got out of hand. Police forces evolved from regular military forces only in the last century or two as specialized wielders of domestic force. Maintaining public order in the face of social protest or colonial unrest was at least as important as fighting crime. Police and army retained strong links in values, organization, and technique; donning uniforms, in fact, regularly


marked the critical, and sometimes contested, point when constables became policemen.85

But military institutions, as I have tried to suggest, include still more. Consider the host of scientists, engineers, and technicians who now draw their funding in greater or lesser degree from military budgets and how that influences the course of research.84 Military institutions also must include the ostensibly civilian functionaries who staff the Pentagon, as well as the academic theorists of nuclear warfare who provide much of our current grand strategy.85 Yet military institutions even so broadly defined may still be conceived too narrowly. Ultimately, the state itself is best understood in terms of military institutions.

Military concerns shaped the origin of the state at the dawn of history, chiefly in response to perceived needs for defense against external threat, for seizing resources, and for quelling internal dissent. Moreover, because military institutions played such central roles in the structure of civilized societies, their influence spread widely through the social system. Civilized societies owe much of their distinctive character to the constant, if sometimes obscure, interactions of military with other social institutions.86 Such interactions, in


Barton C. Hacker, “The Invention of Armies: The Origins of Military Institutions, Gender Stratification, and the Labor Process” (paper presented at the annual meeting
particular, promoted the rise of the modern Western nation-state, shaping and reshaping social structures, actions, and values pervasively and persistently.\textsuperscript{89} "A professional army," as Stephen Skowronek recently observed, came to stand "next to a professional civil service as an institutional standard of the modern state."\textsuperscript{88}

Militarism once offered a notable instance of this linkage, but the glorification of armed force and its wielders never told the whole story.\textsuperscript{89} It may now have become, in fact, merely an outmoded story. For the modern industrial state, the normal functioning of military institutions is perhaps better exemplified by the relationships encoded in the term "military-industrial complex."\textsuperscript{90} Though the label has lost some of its former currency, the underlying realities of defense economics remain as cogent as ever in the industrialized world.\textsuperscript{91} And


\textsuperscript{88}Skowronek, Building a New American State (n. 28 above), p. 85.


not only there. Economic order in the Third World now displays many of the same traits.\textsuperscript{92}

Other aspects of the modern social order likewise reflect the influence of military institutions. One example is the place of women. Historically, women played crucial, though largely overlooked, military roles, a matter of some significance in understanding their present status in the armed forces.\textsuperscript{93} More important, the structure of gender in modern society cannot be fully explained without recourse to links between military and other social institutions.\textsuperscript{94} Scouting will perhaps serve as an obvious example.\textsuperscript{95} Yet it is hardly unique. Since the late 19th century, military models have shaped social action as diverse as evangelism and conservation. The military model for the Salvation Army is self-evident.\textsuperscript{96} Less obvious, or perhaps merely less well-known, the Civilian Conservation Corps of the 1930s likewise


adopted military forms and employed military officers to organize its forces and direct its efforts.\(^{97}\) The recent creation of so-called boot camps to impose military discipline on youthful offenders and so save them from their own disorder testifies that the spirit still flourishes.\(^{98}\)

As products of the later 20th century, we tend to find such intimate links between military and other social institutions somehow aberrant, a recent product of unique, or at least unusual, factors. But only our failure to see the significance of military institutions for civilized society is new. "All state organization was originally military organization, organization for war," commented Otto Hintze in a 1906 Dresden lecture. "This can be regarded as an assured result of comparative history."\(^{99}\) Originating in antiquity, that view revived in the Enlightenment, especially among the Scottish social philosophers from David Hume to Adam Smith.\(^{100}\) It eclipsed all others during the 19th century as a way to explain crucial features of political, economic, and social organization. Why that insight faded after World


War I is an interesting question, but one beyond the scope of this article. Suffice to say the answer appears more likely to involve changing intellectual fashion than counterevidence.101

Illuminating interactions between military and other social institutions may offer one of the best reasons for studying military technology. It can provide the visible links between enduring (though not immutable) institutions and the more superficial history of events.102 Technological innovation has historically answered more to military purpose than commonly allowed, ingenious weapons having held Western imaginations in thrall since the Middle Ages.103 Unfortunately, guides to the history of technology tend to obscure the links by making “military technology” a residual category: fortifications disappear into architecture, battleships and bombers into transportation, explosives into chemical technology.104 Military technology took little space in his Bibliography of the History of Technology, Eugene Ferguson explained, “because so much of it is buried under other rubrics.”105 Another problem compounds this shortcoming. Military roots can wither as change ramifies throughout society, the military voice coming to seem merely one among many others. The crucial role of early military sponsorship may then vanish from sight and mind:

103I know of no work that directly addresses this fascinating strand in Western thought, but see Bert S. Hall’s discussion of the medieval military technological tradition in The Technological Illustrations of the So-called “Anonymous of the Hussite Wars,” Codex latinus monacensis 197, Part I (Wiesbaden, 1979), “Introduction,” pp. 11–25; Gille, Engineers of the Renaissance (n. 38 above). For more recent manifestations, see Mary Kaldor, The Baroque Arsenal (New York, 1981); H. Bruce Franklin, War Stars: The Superweapon and the American Imagination (New York, 1988).
witness the career of electronics, especially computers. Few who adopt technical or organizational innovations know, or care, about their ultimate source, and higher education continues to bear the burden of military purposes.

Historically, limited resources forced careful choices on a profession already prone to caution by the life-and-death stakes it dealt with. Adopting new weapons remained a chancy affair when choosing one foreclosed another. Since World War II, however, military managers have gained control of unprecedented resources and have learned to harness technological innovation. Imperfect as yet and far too costly, the techniques suggest still another military revolution in the making. The automation of warfare may remain a more distant prospect than enthusiasts claim or critics fear, but we have clearly come around nearly full circle.

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Military technological innovation transformed 19th-century armies. During the century, engineers trained in military schools, working in military settings, and funded with military money spread change throughout the social system. The reordered industrial state of the late 20th century now floods the world with novel arms, and military technological innovation once again promises (or threatens) sweeping changes in the social order. This assumes, of course, that the 20th century's most remarkable innovation in the means of destruction, nuclear weapons, allows the future to happen.