Cavalry to Computer

The Pattern of Military Revolutions

Andrew F. Krepinevich

OVER THE NEXT several decades, the world is destined to experience a revolution in the character of warfare. Indeed, the way in which the United States and its allies won a quick and overwhelming victory in the Gulf War suggests to many that we are already in the early stages of such a military revolution. But if so, there is much more to come.

As it progresses, this revolution will have profound consequences for global and regional military balances, and thus for U.S. defense planning. In the past, military revolutions have induced major changes in both the nature of the peacetime competition between states and their military organizations, as well as in the ways wars are deterred, fought, and resolved. By changing radically the nature of the military competition in peace and war, military revolutions have changed the "rules of the game." In so doing, they have often dramatically devalued formerly dominant elements of military power, including weaponry, weapons platforms, and doctrines. Military organizations that did not adapt in a rapidly changing, highly competitive environment have declined, often quite quickly.

What is a military revolution? It is what occurs when the application of new technologies into a significant number of military systems combines with innovative operational concepts and organizational adaptation in a way that fundamentally alters the character and conduct of conflict. It does so by producing a dramatic increase—often an order of magnitude or greater—in the combat potential and military effectiveness of armed forces.

Military revolutions comprise four elements: technological change, systems development, operational innovation, and organizational adaptation. Each of these elements is in itself a necessary, but not a sufficient, condition for realizing the large gains in military effectiveness that characterize military revolutions. In particular, while advances in technology typically underwrite a military revolution, they alone do not constitute the revolution. The phenomenon is much broader in scope and consequence than technological innovation, however dramatic.

The transition from the Cold War period of warfare to a new military era that is now anticipated may take several decades—or it may arrive within the next ten or fifteen years. There is no common transition period from one military regime to another: the naval transition from wood and sail to the all big-gun dreadnoughts with their steel hulls and turbine engines took roughly half a century; the emergence of nuclear weapons, ballistic missile delivery systems, and associated doctrine and organizational structures took roughly fifteen years. The rate of transition is typically a function not only of the four

Andrew F. Krepinevich is director of the Defense Budget Project and adjunct professor of strategic studies at Johns Hopkins SAIS.

elements noted above, but of the level of competition among the international system's major players, and the strategies the competitors choose to pursue in exploiting the potential of the emerging military revolution.

It may be argued that with recent transition periods of ten to twenty years, we are discussing a continuous military evolution rather than a revolution. But what is revolutionary is not the speed with which the entire shift from one military regime to another occurs, but rather *the recognition, over some relatively brief period, that the character of conflict has changed dramatically, requiring equally dramatic—if not radical—changes in military doctrine and organizations.* Just as water changes to ice only when the falling temperature reaches 32 degrees Fahrenheit, at some critical point the cumulative effects of technological advances and military innovation will invalidate former conceptual frameworks and demand a fundamental change in the accepted definitions and measurement of military effectiveness. When this occurs, military organizations will either move to adapt rapidly or find themselves at a severe competitive disadvantage.

Ten Revolutions

THERE APPEAR TO have been as many as ten military revolutions since the fourteenth century. The Hundred Years' War (1337-1453) spawned two of them. The first was the so-called *Infantry Revolution*, which saw infantry displacing the dominant role of heavy cavalry on the battlefield.[1] During the period leading up to this military revolution, infantry typically employed tight formations of pole-arms and crossbowmen to protect the cavalry while it formed up for a charge. During the first half of the fourteenth century, however, the infantry—in the form of Swiss pikemen and English archers—emerged as a combat arm fully capable of winning battles, as was demonstrated at the battles of Laupen (1339) and Crecy (1346).[2] Following these engagements, major cavalry actions on the field of battle became increasingly rare.

Clifford Rogers cites several factors as responsible for the Infantry Revolution. One key factor was the development of the six-foot yew longbow, which gave archers a much enhanced ability to penetrate the armor of cavalrymen. It also gave archers both missile and range superiority over their adversaries. England, which developed a pool of yeoman archers over decades of warfare against the Scots and Welsh, established a significant competitive advantage over the formerly dominant army, that of the French, which failed to exploit the revolution until late in the fifteenth century.

But it was not the longbow alone that fueled the revolution. Once the ability of infantrymen to win battles was clearly established, tactical innovations followed. The English developed a tactical system based on integrating archers with dismounted men-at-arms. Interestingly, the dominance of infantry was given an additional boost by the fact that archers were far less expensive to equip and train than men-at-arms. Thus, Rogers points out, the tiny kingdom of Flanders, which was relatively quick in exploiting the revolution, was able to muster a larger army at Courtrai (1302) than the entire kingdom of France. Finally, the Infantry Revolution marked a sharp increase in casualties on the battlefield. Whereas formerly it had been important to capture

[1]Clifford J. Rogers, "The Military Revolutions of the Hundred Years' War," *The Journal of Military History*, April 1993, pp.241-78.

[2]At the Battle of Crecy, for example, the French lost 1,542 knights and lords, and suffered over 10,000 casualties among crossbowmen and other support troops, while the English lost two knights, one squire, forty other men-at-arms and archers, and "a few dozen Welsh." Bernard and Fawn M. Brodie, *From Crossbow to H-Bomb* (Bloomington, IL: Indiana University Press, 1973), pp.39-40.

knights for the purpose of realizing a ransom, common infantrymen neither held that value, nor did they share knightly notions of chivalry. Battles thus became more sanguine affairs.

The Infantry Revolution was succeeded by the *Artillery Revolution*, which dramatically altered war in the latter period of the Hundred Years' War. Although Roger Bacon's recipe for gunpowder dates back to 1267, cannons only began to appear on the European battlefield in significant numbers some sixty years later. Even then, almost a full century passed before artillery began to effect a military revolution. During this period besieged cities typically surrendered due to a lack of supplies. In the 1420s, however, a major increase occurred in the number of besieged cities surrendering as a consequence of the besiegers' artillery fire fatally degrading the cities' defenses. In the span of a few decades, gunpowder artillery displaced the centuries-old dominance of the defense in siege warfare.

Several technological improvements underwrote the Artillery Revolution. One was the lengthening of gun barrels, which permitted substantial increases in accuracy and muzzle velocity, translating into an increase in range and destructive force (and also the rate of fire). Metallurgical breakthroughs reduced the cost of iron employed in fabricating gun barrels, reducing the overall cost of cannons by about a third. Finally, the "corning" of gunpowder made artillery more powerful and cheaper to use.[3] As one Italian observer noted, artillery could now "do in a few hours what...used to take days."[4] Unlike the Infantry Revolution, the Artillery Revolution was expensive to exploit. As early as 1442 the French government was spending over twice as much on its artillery arm as on more "traditional" military equipment.[5]

A kind of snowball effect developed. The richer states could exploit the Artillery Revolution to subdue their weaker neighbors (or internal powerful regional nobles), which in turn increased the resources available to exploit their advantage further. This phenomenon was a significant factor in the growth of centralized authority in France and Spain. Along with the changes in technologies that spawned the great improvements in artillery and changes in siege warfare, new military organizational elements, such as artillery siege trains, were formed to cement the revolution. Once this occurred, defenders could no longer rely on castles for protection. This led to further changes in military organizations and operations, as the defenders now had to abandon their fortified castles and garrison units and move the contest into the field. And, as Francesco Guicciardini wrote, "Whenever the open country was lost, the state was lost with it."

Military revolutions were not limited to land. The *Revolution of Sail and Shot* saw the character of conflict at sea change dramatically, as the great navies of the Western

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[3]"Corning" involves mixing wet powder and allowing it to dry into kernels. It is purported to have been three times as powerful as the sifted form, and considerably less expensive. Other improvements included the introduction of the two-wheel gun carriage, trunnions, and iron cannonballs. See Rogers pp. 269-71.

[4]Guicciardini, Francesco, *History of Italy* (New York: Washington Square Press, 1964), p. 153.

[5]Rogers also notes that, although the technology and military weapon system had been perfected, when military organizations failed either to restructure effectively, whether through a lack of funds or organizational insight, they failed to achieve the benefits of a revolutionary increase in military effectiveness. For example, when the siege train was relatively weak, as was the case during the sieges of Guise (1424), Ferte-Bernard (1424), Torey Castle (1429), Chateau Gallard (1429), Laigny-sur-Marne (1432), and Harfleur (1440), the siege dragged on for from between three months to over a year.

world moved from oar-driven galleys to sailing ships that could exploit the Artillery Revolution by mounting large guns. Galleys, being oar-driven, had to be relatively light, and, unlike ships propelled by sail, could not mount the heavy cannon that could shatter a ship's timbers, thus sinking enemy ships rather than merely discouraging boarding parties. Indeed, prior to the late fourteenth century, ship design had not improved significantly for two millennia, since the age of classical Greece. The French first mounted cannons on their sailing ships in 1494. But the death knell for the galley did not sound clearly until the Battle of Preveza, when Venetian galleasses won an overwhelming victory against Turkish galleys. The result was repeated at Lepanto in 1571.[6] By 1650 the warship had been transformed from a floating garrison of soldiers to an artillery platform.

The sixteenth century witnessed the onset of the *Fortress Revolution*, which involved the construction of a new style of defensive fortification employing lower, thicker walls featuring bastions, crownworks, ravelins, and hornworks, all of which were part of a defensive fortification system known as the *trace italienne*. As Geoffrey Parker observes, "normally the capture of a stronghold defended by the *trace italienne* required months, if not years." Static defenses thus effected a kind of "comeback" against the Artillery Revolution. However, as with artillery, the new fortification system was terribly expensive, a fact that limited its application and left considerable opportunity for operations in the field. This, in turn, shifted the focus back to infantry, where revolutionary developments permitted a new use of firepower; infantry moving beyond archers to the combination of artillery and musket fire on the battlefield in what might be termed the Gunpowder Revolution.

Muskets capable of piercing plate armor at a range of one hundred meters were introduced in the 1550s. The English abandoned longbows in the 1560s in favor of firearms. Finally, in the 1590s the Dutch "solved" the problem of muskets' slow rate of fire through a tactical innovation that saw them abandon the tight squares of pikemen in favor of drawing up their forces in a series of long lines. These linear tactics allowed for a nearly continuous stream of fire as one rank fired while the others retired to reload. Muskets were also attractive because they required little training in comparison to the years necessary to develop a competent archer (although linear tactics did require considerable drill). The large, tight squares of pikemen, which had proved so effective against cavalry, now became attractive targets for musket and artillery fire.

This revolution reached full flower in the campaigns of Gustavus Adolphus during the Thirty Years' War, which saw the melding of technology, military systems, operational concept, and new military organizations: a combination of pike, musketeers, cavalry and a large rapid-firing artillery component utilizing linear tactics—what has been described as the Swedish military system—yielded stunning success at Brietenfeld, Lutzen, Wittstock, Brietenfeld II, and Jankov.[7]

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[6]Brodie, p. 64 and Geoffrey Parker, "The Western Way of War," lecture presented at the Johns Hopkins SAIS, February 17, 1994, p. 87. Parker goes on to note that the galley, while displaced as the centerpiece of naval warfare, did manage to survive, and even prevail on occasion, into the eighteenth century.

[7]Gustavus Adolphus actually *increased* marginally the ratio of pike to shot when compared to the Dutch. However, he did it in such a way as to promote the integration of pike, shot, artillery, and cavalry into combined arms operations. See Michael Roberts, "The Military Revolution, 1560-1660," *Essays in Swedish History* (Minneapolis: University of Minnesota Press, 1967); Geoffrey Parker also argues that a third military revolution (or perhaps more accurately, a third element of the military revolution) involved the radical increase in the size of armies that occurred in the latter part of the seventeenth century, or, more precisely, between 1672 and 1710.

Linear tactics were perfected under the Prussian military system of Frederick the Great, who achieved significant improvements in the rate of fire, as well as major improvements in supply. But this refined system would be overturned by the *Napoleonic Revolution.*

The French were the first to exploit the potential for a military revolution that had been building for several decades prior to Napoleon's rise to prominence. During this period, thanks to the emerging Industrial Revolution, the French standardized their artillery calibers, carriages and equipment, and fabricated interchangeable parts. Other improvements in industrial processes allowed the French to reduce the weight of their cannon by 50 percent, thereby increasing their mobility while decreasing transport and manpower requirements dramatically.

The introduction of the *levée en masse* following the French Revolution helped to bring about another quantum leap in the size of field armies. Men proved much more willing to defend and fight for the nation than the crown. Consequently, France's revolutionary armies could endure privations, and attack almost regardless of the cost in men (since they could call upon the total resources of the nation). In battle, the individual could be relied upon; skirmishers and individually aimed fire could be integrated to great effect into the rolling volleys of artillery and musketry. Furthermore, armies became so large that they could now surround and isolate fortresses while retaining sufficient manpower to continue their advance and conduct field operations, thus largely negating the effects of the *trace italienne* and the Fortress Revolution.

The latter part of the eighteenth century also witnessed the creation of a new self-sufficient military organization—the division—and saw the growing importance of skirmishers in the form of light infantry, and cavalry as a reconnaissance, screening, and raiding force. A growing network of roads in Europe meant it was possible for an army to march in independent columns and yet concentrate quickly. Coordination was also improved through the availability of much more advanced cartographic surveys.

Napoleon's genius was to integrate the advances in technology, military systems, and military organizations (including his staff system) to realize a dramatic leap in military effectiveness over the military formations that existed only a short time before. Indeed, it took the other major military organizations of Europe at least a decade before they were able to compete effectively with the *Grande Armée* that Napoleon had fashioned to execute what one author has termed the "Napoleonic blitzkrieg."

Between the Napoleonic Wars and the American Civil War, the introduction of railroads and telegraphs, and the widespread rifling of muskets and artillery again dramatically transformed the character of warfare—the way in which military forces are organized, equipped, and employed to achieve maximum military effectiveness. The result was the *Land Warfare Revolution.* In the Civil War, both the Union and the Confederate forces used their rail nets to enhance greatly their strategic mobility and their ability to sustain large armies in the field for what, in the war's final year, was continuous campaigning. Their exploitation of the telegraph facilitated the rapid transmission of information between the political and military leadership and their commanders in the field, as well as among the field commanders themselves. The telegraph also dramatically enhanced the ability of military leaders to mass their forces quickly at the point of decision and to coordinate widely dispersed operations far more effectively than had been possible during the Napoleonic era.

The effects of rifling, which improved the range and accuracy of musketry and artillery, were not as quickly appreciated by the American military. Union and Confederate generals who clung to the tactics of the Napoleonic era exposed their men to fearful slaughter, as at Fredericksburg,

Spotsylvania, and Gettysburg. The introduction of repeating rifles in significant numbers late in the conflict enabled the individual soldier to increase substantially the volume, range and accuracy of his fires over what had been possible only a generation or two earlier. One Confederate general is said to have observed that "had the Federal infantry been armed from the first with even the breechloaders available in 1861, the war would have been terminated within a year."[8] Still, both sides did adapt eventually.

The campaigns of 1864 and 1865 were marked by the proliferation of entrenchments and field fortifications. Indeed, by the time Sherman's men were marching from Atlanta to the sea in 1864, they lightened their packs by throwing away their bayonets—but they kept their shovels. Shelby Foote notes that the Confederate forces opposing Sherman had a saying that "Sherman's men march with a rifle in one hand and a spade in the other," while Union troops felt that "the rebs must carry their breastworks with them." Arguably, many of the major battles toward the war's end bore a greater resemblance to operations on the Western Front in the middle of World War I than they did to early Civil War battles like Shiloh or First Manassas.

Over the next fifty years this new military regime matured. The increases in the volume, range, and accuracy of fires were further enhanced by improvements in artillery design and manufacturing, and by the development of the machine gun. Again, military leaders who ignored, or who failed to see clearly, the changes in warfare brought about by technological advances and who failed to adapt risked their men and their cause. This myopia was induced partly by the fact that no large-scale fighting occurred among the great powers of Europe between 1871 and 1914. World War I provides numerous examples of this phenomenon, as the military regime that began with the mid-nineteenth century revolution in land warfare reached full maturity. One recalls here the mutiny of the French army after the futile and bloody Nivelle Offensive, the appalling casualties suffered by the British at the Somme and Passchendaele, and by the French and Germans at Verdun.

Just trailing this revolution in land warfare was the *Naval Revolution*. The Revolution of Sail and Shot had long since matured. The wooden ships that were powered by the wind and armed with short-range cannon that had dominated war at sea had not changed appreciably since the sixteenth century. But over the course of a few decades of rapid change from the mid-1800s to the first years of the twentieth century, these vessels gave way to metal-hulled ships powered by turbine engines and armed with long-range rifled artillery, dramatically transforming the character of war at sea. As persistent challengers to British naval mastery, the French consistently led the way early in the Naval Revolution.[9] In 1846 they pioneered the adoption of steam propulsion and screw propellers on auxiliary ships. In 1851 they launched the *Napoleon*, the first high-speed, steam-powered ship of the line. And in the late 1850s, France began constructing the first seagoing ironclad fleet. The British,

[8]Brodie, p. 136. Shelby Foote observes that the Sharp repeating rifles employed by Union troops late in the war gave a cavalry force of 12,000 more firepower than an entire corps of infantry. See Foote, *The Civil War: A Narrative* (New York: Vintage Books, 1986), Vol. III, p. 872.

[9]For a discussion of the early period of this revolution, see Bernard Brodie, *Sea Power in the Machine Age* (Princeton: Princeton University Press, 1942), pp.48, 52, 66-68, 75-76, 195; Terrence R. Fehner, *National Responses to Technological Innovations in Weapon Systems, 1815 to the Present* (Rockville: History Associates Incorporated, 1986), pp.7-14; and William H. McNeill, *The Pursuit of Power: Technology, Armed Force, and Society Since A.D. 1000* (Chicago: University of Chicago Press, 1982), pp.227-28, 239, 291-92.

however, quickly responded to these French innovations, taking the lead in applying these technologies. The mature phase of this revolutionary period found Britain attempting to sustain its position against a new challenger, Imperial Germany, by launching the first all-big-gun battleship, *H.M.S. Dreadnought*, in 1906. This period also saw the introduction of the submarine and the development of the torpedo. Indeed, the development of these two instruments of war led to the introduction in World War I of entirely new military operations—the submarine strategic blockade and commerce raiding, and anti-submarine warfare.

Toward that war's end, however, new operational concepts were developed to mitigate the effects of the dominant military systems and operational concepts. On land, massed frontal assaults preceded by long artillery preparations gave way to brief artillery preparation fires, infiltration tactics, and the use of the light machine gun as the dominant weapon of the German storm trooper assault. At sea, Great Britain and the United States established elaborate convoy operations to counter the U-boat threat that had transformed the nature of commerce raiding.

World War I both represented the mature stage of one military epoch, and presaged the rise of the *Interwar Revolutions in Mechanization, Aviation, and Information*. As the war progressed, the land forces of both the Allied and the Central powers found themselves employing new military systems based on dramatic advances in the fields of mechanization and radio. Following the war, improvements in internal combustion engines, aircraft design, and the exploitation of radio and radar made possible the *blitzkrieg*, carrier aviation, modern amphibious warfare, and strategic aerial bombardment. Entirely new kinds of military formations appeared, such as the panzer division, the carrier battlegroup, and the long-range bomber force. After a scant twenty years, the nature of conflict had changed dramatically, and those—like the British and the French—who failed to adapt suffered grievously.

Finally, in the mid-twentieth century, the *Nuclear Revolution* (especially after the coupling of nuclear warheads to ballistic missiles), brought the prospect of near-instantaneous and complete destruction of a state's economic and political fabric into the strategic equation. Here was a shift in technology so radical it convinced nearly all observers that a fundamental change in the character of warfare was at hand. Indeed, in the eyes of some observers, once nuclear weapons were stockpiled in significant numbers by the superpowers, they could no longer be employed effectively. Their only utility was in deterring war. Nevertheless, one also sees here the emergence of very different warfighting doctrines and military organizations among nuclear states (e.g., the U.S. nuclear submarine force; Soviet Strategic Rocket Forces).

Seven Lessons

REFLECTING ON THIS record extending over seven centuries, it is possible to make some general observations about the character of military revolutions.

First, and to reiterate a point made earlier, emerging technologies only make military revolutions possible. To realize their full potential, these technologies typically must be incorporated within new processes and executed by new organizational structures. In the cases outlined above, all major military organizations fairly rapidly gained access to the emerging technologies. Failure to realize a great increase in military effectiveness typically resulted not so much from ignoring technological change as from a failure to create new operational concepts and build new organizations.

Perhaps the clearest example of the importance of organizational innovation occurred early in World War II. On the Western Front in 1940, British and French armored forces were roughly equal to the

Germans' in size, and in quality. Both the allies and the Germans had modern aircraft and radios. In the interwar years, however, it was the German military that had identified both the operational concept to best integrate these new military systems and the organization needed to activate that concept. The result was a major increase in military effectiveness and the acquisition of a decisive comparative advantage. Germany defeated the allied forces and conquered France in six weeks. That victory was primarily due to the *intellectual* breakthroughs that led to new operational concepts and the organizational flexibility that allowed them to exploit these concepts.

A *second* lesson is that the competitive advantages of a military revolution are increasingly short-lived. Military organizations typically recognize the potentially great penalties for failing to maintain their competitive position. In early periods of military revolution, it was possible to maintain dominance for a relatively long period (witness the sluggish response of France to the Infantry Revolution and much of Europe to the Napoleonic Revolution). But since the Napoleonic era, it has been true that if a major military organization is to derive an advantage by having first access to new technologies it has to exploit those technologies quickly, before its major competitors copy or offset the advantage.

For example, the French innovations that sparked the nineteenth century Naval Revolution stimulated a furious British response that matched and then exceeded the French effort. Although the British were loath to introduce radical changes in ship design, they felt compelled to when faced with the French initiative, and retained a major advantage. What gave Britain its competitive advantage was its economic strength, its ability to tap into that strength through its financial system, and its ability to concentrate its resources on a naval competition in a way that France, a continental power, never could. As the revolution matured, France's fleeting opportunities evaporated.

By the end of the Naval Revolution, the tables were again turned. When the British launched *H.M.S. Dreadnought*, Germany quickly took up the British challenge, leading to the Anglo-German dreadnought arms race. Thus, the Royal Navy's lead in applying technologies to launch the first all-big-gun battleship designed to make all others "obsolete" produced only an ephemeral competitive advantage over Germany, and the other major navies of the world, which quickly constructed their own "dreadnoughts."

Indeed, in the last two centuries there do not seem to be any prolonged "monopolies" exercised by a single competitor in periods of military revolution. Fairly quickly, major powers who can afford the technology and who understand how to employ it, have it if they want it. Of course, one is immediately led to ask the question: Is "fairly quickly" quickly enough? After all, Admiral Alfred von Tirpitz, who directed Germany's naval buildup, viewed with alarm the period from 1906, when Britain launched *Dreadnought*, to 1910, when Germany's naval building program was able to offset partially the British advantage. It may be that although the period of competitive advantage appears to be fairly short there may be a potentially great advantage from being first, as the French discovered to their dismay and the Germans to their elation in the spring of 1940.

Having the initial competitive advantage in a period of military revolution—even if that advantage is considerable—is no guarantee of continued dominance, or even competitiveness. The list of military organizations that established an early lead, only to fall behind later, is long. Consider the history of the submarine: the French navy made much of the early progress in submarines in the late nineteenth century, but it was the Kaiser's navy that employed the new system to such devastating effect in World War I. In World War II, the United States quickly adopted many of Germany's innovations in mechanized air-land operations and in sub-

marine commerce raiding. Or take military aircraft: the Americans were in the forefront of aviation in the first years of the twentieth century, but by the time of their entry into World War I had fallen substantially behind many European states. Or tanks: an American tank designed in the 1920s was adapted by the Soviets in the process of developing the T-34, one of the most effective tanks to emerge during World War II. The U.S. Army, on the other hand, was equipped during the war primarily with the inferior Sherman tank.

Even though monopolies may be fleeting, they are real and often decisive in war. The early years of World War II—in some respects like the Napoleonic era revolution in land warfare during the late eighteenth century—demonstrate what can happen when only one power is innovative and adaptive. In the run-up to that war, Germany proved far more adept than France, Britain, and Soviet Russia at operational and organizational innovation on land. Although the Soviet Union, Great Britain, and the United States caught up to Germany's blitzkrieg in the span of a few years, France was unable to adapt quickly enough in 1940 to avoid disaster, while Soviet Russia suffered enormous devastation at the hands of the German war machine.

A *third* lesson of history is that asymmetries in national objectives and strategic cultures, as well as limitations on resources and the potential number and strength of enemies, allow for niche, or specialist, competitors. This phenomenon seems to be characteristic of recent periods of military revolution, where technological change has been broadening and accelerating, offering a potentially rich menu of military innovation. Furthermore, the cost of competing imposes strong limitations on how a military organization will pursue the competition. Again, the best example of this phenomenon occurred during the Interwar Revolutions in Mechanization, Aviation, and Information. With one exception, the period was characterized by selective competition among the military organizations of the great powers. For example, for a time Germany, traditionally a land power, became dominant in mechanized air-land operations. Soviet Russia quickly joined that competition to survive. Japan, an island nation, competed in naval aviation and modern amphibious operations, while the British developed strong capabilities in strategic aerial bombardment, strategic defenses, and (arguably) modern amphibious operations. Only the United States had the resources to compete in every major area of the interwar military revolution (save strategic defenses, for which it had no need), while simultaneously positioning itself to exploit the coming military revolution in nuclear weapons. Clearly the level and sophistication of human and material assets, and the unique strategic circumstances faced by each competitor, shape how competitors approach and attempt to exploit the opportunities inherent in military revolutions.

Fourth, the historical record suggests that war and revolution in warfare are quite separate entities. True, it took the test of World War II to convince the world's major army organizations (and, one might add, much of the German army itself) that Germany's blitzkrieg concept could produce great advantages for its practitioners. The war also convinced the U.S. Navy and the Imperial Japanese Navy that aircraft carriers would be the new centerpiece of battle fleets, and convinced everyone to recognize the revolution in naval warfare brought on by the use of submarines. But a confirming war is not essential for military organizations to seize opportunities. For instance, the revolution in naval warfare in the late nineteenth century, from wood, sail, and cannon to steel, turbines, and rifled guns, was widely accepted in the absence of war. The introduction of nuclear weapons is another obvious example of broad acceptance by military organizations that the competitive environment had changed radically.

Fifth, though most militaries will be quick to recognize a competitor's advantage, there are no certainties. Not even war will guarantee that all military organizations will recog-

nize and exploit a military revolution, or understand a revolution in all its dimensions. Thus, in the American Civil War, both sides were relatively quick in exploiting the dramatic gains in strategic mobility and command, control, and communications made possible by the railroad and telegraph. But years passed before either side clearly realized how drastically the appearance of rifled guns and muskets in large numbers had invalidated the Napoleonic battlefield tactics. Again, despite the experience of World War I the world's major naval powers tended to discount the effectiveness of strategic warfare conducted by submarines. And even after the German campaign in Poland alerted the world to the potential of the blitzkrieg, the French army remained remarkably, indeed fatally, resistant to innovation.

More than anything else, it is perceptions of future contingencies and likely enemies that determine whether and when there is full exploitation of the advantages offered by the military revolution. Having a single enemy or challenger may ease a military organization's problem by making it more manageable. For instance, Britain had three major kinds of naval contingencies to prepare for in the interwar period: a war against a major continental power in Europe; a "small war" involving its imperial possessions; and a war against Japan. Conversely, the world's two other major maritime powers, the United States and Japan, saw each other as by far their most prominent challenger, and organized their naval forces around a single contingency—a Pacific war. As it turned out, the Americans and the Japanese exploited the revolution in naval aviation far more proficiently than did the British, in part because of their ability to focus more precisely. In competing during a period of military revolution it is clearly advantageous to be able to identify not only the nature of future conflict but specific contingencies and competitors. But if that is not possible, a premium should be placed on possessing both sufficient organizational agility and resources to adapt quickly if or when the picture clarifies.

A *sixth* lesson is that technologies that underwrite a military revolution are often originally developed outside the military sector, and then "imported" and exploited for their military applications. Thus, in the early fourteenth century, the Artillery Revolution was fueled by the discovery that the method being used to cast church bells could also be used for casting artillery—so that, as Bernard Brodie observes, "the early founders, whose task had been to fashion bells which tolled the message of eternal peace...contributed unintentionally to the discovery of one of man's most terrible weapons." The development of the railroad and telegraph, which helped to effect the Revolution in Land Warfare, and the rise of the commercial automotive and aircraft industry which led to the Interwar Revolution, are other obvious examples. Indeed, all the military revolutions of the last two centuries are in a real sense spinoffs from the Industrial and Scientific Revolutions that have been central, defining processes of modern Western history.

That said, having a substantially inferior economic and industrial base need not be an absolute barrier to competition in a military revolution. During the interwar period the Imperial Japanese Navy developed a first-rate naval aviation capability and modern amphibious forces, which they employed to devastating effect in the early months of their war with the United States. The Japanese accomplished this with a gross national product that was less than 20 percent (and perhaps closer to 10 percent) of that of the United States, its major naval competitor in the Pacific. Again, following World War II, the Soviet Union, despite a German invasion that destroyed much of its most productive areas, developed with relative speed a nuclear weapon strike force to rival that of the United States. This was accomplished even though the Soviet Union's GNP was much lower than that of the United States, and it was burdened by war reconstruction costs and the maintenance of a far larger conventional military force.

However, in neither case could this competitive posture be sustained indefinitely against a wealthier, equally determined rival.

In a sense, military revolutions may offer major opportunities for relatively small or "medium-sized" powers to steal a march on greater powers, or even for one great power to challenge an array of its peers. They do so by making it possible to substitute intellectual breakthroughs and organizational innovations for material resources. Examples are plentiful: Flanders exploiting the Infantry Revolution to challenge giant France; the Napoleonic Revolution that allowed France to challenge all of Europe; Germany's innovations (in mechanized air-land operations) during the Interwar Revolution against France, Britain, the Soviet Union, and the United States; and Japan exploiting the Interwar Revolution (in naval aviation) against the United States and Great Britain. Indeed, as Geoffrey Parker has argued, the West's global dominance from 1500-1800 is but an instance of this phenomenon writ large.

A *seventh* and last lesson is that a military revolution does not ineluctably imply a quantum leap in the cost of maintaining military forces. To take one example, the Infantry Revolution of the fourteenth century that replaced heavy cavalry with infantry archers and pikemen actually lowered the cost of maintaining forces. Also, the Nuclear Revolution has been comparatively cheap. While the ability to employ such weapons to achieve political ends has been much debated, the fact remains that nuclear weapons appeared to offer those who possess them considerable "bang for the buck."[10]

The Current Revolution

WHERE ARE WE now? Some believe that a revolution in warfare has already occurred, and cite the recent Gulf War as evidence. American military operations in that war, however, do not meet the historical criteria for revolutionary change. United States forces did not display any dramatic doctrinal changes in that war, nor any major new force structures or military organizations. One indication of how continuous with earlier practice the U.S. performance was is that during the U.S. "Linebacker" air operations in 1972, some nine thousand laser-guided bombs were dropped on Southeast Asia—roughly the same number as were dropped during the Gulf War. We are in a military revolution—but in its early stages.

What the Gulf War did was show us a glimpse of the potential influence of this revolution on military effectiveness. The Gulf War may be seen as a *precursor war*—an indication of the revolutionary potential of emerging technologies and new military systems. In this respect, it may be similar to the battle of Cambrai that took place on the Western Front in November 1917. There the British, for the first time, employed large numbers of planes and tanks in concert. They tried to integrate their operations, and those of the infantry and artillery, through the use of wireless communications. The British attack, spearheaded by nearly five hundred tanks, broke the German lines on a twelve kilometer front within hours.

This breakthrough was as surprising to the senior British leaders as the one-sided Desert Storm operation was to senior

[10]While this point is often made, its acceptance is far from universal. For example, the United States is just now beginning to face up to the enormous environmental costs associated with its nuclear weapons program. The cleanup costs are estimated to range from $150-200 billion over thirty years. The situation in the former Soviet states is considered to be far worse. See Government Accounting Office, *DoE Management: Consistent Cleanup Indemnification is Needed*, GAO/RCED-93-167 (Washington, DC: Government Accounting Office, July 1993). Still, it is not clear that long-term environmental costs will weigh heavily with the rulers of most of the countries that are now actively pursuing a nuclear capability.

American commanders. Indeed, the British had made no plans to exploit such a rapid rupture of the German front. In retrospect, one also realizes that the potential for far greater success at Cambrai was compromised by the immaturity of the new technologies and systems employed (tank breakdowns, limitations on aircraft bomb loads, and on wireless range, portability and reliability). To extend the analogy, we may be in the "early 1920s" with respect to this military revolution.

Where are we going? While precise prediction is out of the question, it is possible to speculate with some confidence on the current revolution's general path and nature. It appears certain that it will involve great increases in the ability of military organizations to detect, identify, track, and engage with a high degree of precision and lethality far more targets, over a far greater area, in a far shorter period of time, than was possible in the Cold War era. (No doubt it also will lead to systems and operations designed to degrade or offset these capabilities.) This aspect of the revolution will probably involve an improved ability to understand target *systems* and their relationship to operational and strategic objectives. The leverage obtained from such a capability is potentially enormous, since knowing *which* subset of targets to strike out of the many identified will be crucial to the effective employment of large numbers of precision weapons.

Furthermore, the growing importance of simulations—from computer-assisted design and manufacturing (CAD-CAM), to individual training simulators, to simulations of complex military operations involving high levels of systems and architecture integration—may witness a major increase in the ability of military organizations to extract the full potential of the human and material resources at their disposal.[11]

The transition rate to this revolution's mature stage will be a function of the level of military competition in the international system, the strategies for competition pursued by the competitors, and the four elements comprising a military revolution. It should also be appreciated that, as long as there are multiple competitors exploiting the potential of the emerging military revolution, the revolution itself will be likely to take several paths, if only because of the competitors' varying strategic goals, access to relevant resources, and strategic culture.

What It Means For Us

PERHAPS, AS MANY believe, the United States and the world's other great powers have an opportunity unparalleled in this century to construct an international system that will provide a stable, enduring era of relative peace. Even if there is time and even if the opportunity is grasped, the question will remain: Will it last? Is it possible to avoid, or even forestall, a resumption of the great power competition that has been a staple of the international system since the rise of nation-states? If history is any indicator, the United States will, at some point, find itself again in a military competition, in the midst of both a geopolitical and a military revolution. What can the world's dominant military power learn from the general lessons of the West's prior military revolutions?

First, the United States should anticipate that one or more competitors seeking to exploit the coming rapid and dramatic increases in military potential may soon arise. Remembering that monopolies are transient, the United States should ponder how to

[11]For a more complete discussion, see Andrew F. Krepinevich, "La Révolution à Venir dans la Nature des Conflits: Une Perspective Americaine," in *Relflexions sur la Nature des Futurs Systèmes De Defense*, Alain Baer, ed., (Paris: Ecole Polytechnique, November 1993); and Andrew F. Krepinevich, "Une Révolution dans les Conflits: une Perspective Americaine," *Defense Nationale* (January 1994).

avoid such a competition, or how to postpone it for as long as possible. Or how to win it if necessary.

Second, continued American technological and operational leadership is by no means assured. During the Interwar Revolution, Great Britain held an initial dominant position in mechanized air-land and naval aviation operations that was quickly forfeited. Even when countries will not be able to compete in the full spectrum of military capabilities, some of them, by specializing, will become formidable niche competitors.

Third, it is by no means certain that competitors will follow the same path as the United States. Different security requirements and objectives, strategic cultures, geostrategic postures, and economic situations will likely lead different competitors in different directions. While there are those who believe that, given our current advantage, this military revolution will only progress at a pace and direction that the United States decides to give it, history suggests that this is a dangerous delusion.

Fourth, it is not clear that the United States can rely on the cost of competition acting as an effective barrier to others. Although most military revolutions have raised the cost of "doing business," sometimes dramatically, there have been significant exceptions—and in terms of direct and initial costs the Nuclear Revolution is one of them, and, with proliferation very much at issue, this revolution is still very much with us. If much of the increase in military effectiveness in this emerging revolution stems from the so-called Information Revolution, which has dramatically lowered the cost of information-related technologies, competitors may find the barriers to competition relatively low. And given the history of military organizations adapting technologies initially developed in the commercial sector, the United States' ability to restrict access to these technologies, in the manner it attempted with nuclear fission and missile technologies, may be marginal at best.

In summary, the lessons of earlier revolutions seem to contradict much of the conventional wisdom with respect to the United States' prospective competitive military position. In a revolutionary epoch, long-term U.S. military dominance is not preordained. Indeed, one could argue that the prospects for continued U.S. dominance would be greater in a military regime that was entering early maturity, rather than in its early, most dynamic stages. If America wants to avoid or delay a resumption of military competition, it will have to identify a strategy for that purpose and pursue it energetically. If a competition cannot be avoided, the United States will begin with strong competitive advantages in terms of technology and military systems. As we have seen, however, it is typically those military organizations that are highly innovative and adaptive that seem to compete best in periods of military revolution. In those terms, it has yet to be clearly demonstrated that the United States military should be sanguine regarding its ability to respond effectively to the challenge that this revolution will likely pose. □