7 Technology and Warfare

ELIOT COHEN

Chapter Contents

Reader's Guide

Although the development and integration of technology into military forces and strategy is often depicted as a simple matter, the role of technology in war is controversial. Debate exists about the relative importance of technology when compared to other factors such as training or morale, in achieving victory in battle. Scholars also offer competing explanations about how and why certain technologies are integrated into military organizations while others are ignored. The pace of technological change also is not uniform: some technology and procedures become fixtures in militaries while others become obsolete quickly and are discarded. To complicate matters further, some observers today believe that the world is witnessing a revolution in military affairs, a relatively rare event when technologies are combined to produce a fundamental transformation in the way war is fought. This chapter explores these issues and describes some changes that the revolution in military affairs is producing in military organizations. It also offers some observations about the emerging technological trends that are likely to transform future warfare.

Technophiles and Technophobes

Military historians—and sometimes soldiers themselves—cannot make up their minds about how to view military technology. Some technical experts and enthusiasts are fascinated by the nuances of the various models of the German Panzerkampfwagen Model IV; much contemporary policy debate centres on technical decisions—how many aircraft to buy, what type, over what period of time, and so on. The public at large tends to ascribe remarkable—sometimes even magical—properties to modern military technology.

By contrast, many military historians and soldiers deprecate the importance of technology. They believed that the skill and organizational effectiveness, not pieces of hardware, determine the outcome of battle. Although technical enthusiasts and sceptics sometimes clash in their assessment of a particular contest, rarely does the debate occur at a conceptual level. Only one major figure in the last century—Major General J. F. C. Fuller, a British war planner, pioneer of armoured warfare, and prolific military historian—attempted to write theoretically about the role of technology in strategic studies (1945, 1932, 1926, 1942). This chapter therefore introduces some concepts about military technology, and then discusses the key technological issues and trends of our time.

Some Ways of Thinking about Military Technology

Consider as a point of departure the question: 'Where does military technology come from?' We often think of technology as something predetermined. In this common view, scientists develop technology in war much like people walking down a corridor lined with closed rooms containing treasure chests. Progress consists of walking along the hallway, unlocking the doors, and picking up the chests. The fruits of technology, in other words, lie available to those who have the keys to the doors and the strength to carry away the treasure chests.

In fact, however, historians of technology and engineering usually reject this view. A variety of forces shapes technology, whose final form is far from being predetermined (MacKenzie 1990). The most common view along these lines is that 'form follows function': military technology evolves to meet particular military needs. There are, however, other possibilities. One author, Henry Petroski, talks about 'form following failure', a concept first applied to his study of the history of bridge building, but applicable to military technology as well (1982). In this view, new technology emerges as a response to some perceived failure or fault in existing technology. Other theories of technological invention include the suggestion that technologies emerge from aesthetic or other non-rational considerations, such as custom or organizational convenience (Creveld 1989). These different theories offer varying explanations of how innovation occurs or fails to occur. Why, for example, did it take more than thirty years for the United States, which successfully deployed unmanned aerial vehicles (UAVs) in Vietnam, to introduce them into the armed forces? The technology may have been immature (the corridor-and-doors theory); there may have been no mission crying out for UAVs (form follows function); there may have been no visible failure in the existing technology (form follows failure); or, finally, the technology may have been thwarted by pilots hostile to the notion of aircraft without pilots (non-rational explanations).

No one of these theories is completely satisfying. Their very range, however, should prompt us to look more closely at how and why military technologies come into existence. There are distinctive national styles, for example, in military technology: the Israeli Merkava tank differs subtly from American M1 Abrams. These changes reflect differences in design philosophy stemming from where the two countries believe they will fight (the slow Israeli tank is designed for the rocky Golan Heights; the much faster Abrams tank can exploit its high speed best in desert warfare). The Israelis have given exceptionally high value to crew safety. They accepted mechanical inefficiency by placing the engine in front of the crew space rather than (as is normal) behind it. In armoured warfare, most hits occur on the frontal armour of the tank, and the engine can thus absorb the impact of a hit. The Americans, by purchasing a fuel-hungry high-powered turbine engine, assumed that they could readily resupply their tanks with fuel in vast quantities on the battlefield.

National styles in technology may reflect political assumptions about war at the time that a design was frozen. In 2006, for example, the United States was poised to buy large numbers of the Joint Strike Fighter (JSF), a short-ranged fighter bomber. This decision reflects a political assumption, namely, that the United States would fight its wars within a few hundred miles of its opponents, and, presumably, with extensive access to secure fixed bases.[1]

BOX 7.1

The M1A2 vs the merkava

	M1A2	Merkava (Mk3)
Weight (fully armed) (tons)	69.54	62.9
Length (gun forward) (metres)	9.8	8.8
Height (metres)	2.9	2.8
Width	3.7	3.7
Range (miles)	265	311
Crew	4	4
Road speed (km/hour)	90+	55
Main armament	120 mm	120 mm
Engine	Gas turbine	Diesel

Although similar in some respects, the Merkava is very different from the M1 in others. It is much slower (perhaps half as fast): the Israelis value absolute speed much less than the ability to manœuvre under fire, particularly over the lava-strewn Golan Heights. They also lack the super-fast infantry fighting vehicles to keep up with the tanks. There is a rear hatch on the Merkava that allows the evacuation of wounded or resupply of ammunition without exposing the crew—again, requirements derived from the peculiar problems of keeping a firing line on the Golan Heights. Finally, the Israeli engine is at the front of the tank, where it can absorb an incoming round—a sacrifice of mechanical efficiency for crew protection. The M1 gets a similar effect by unusually good (and expensive) armour.

Sources: http://.army-technology.com/projects/merkava/specs.html; http://www.army-technology.com/projects/abrams/index.html specs. Note: the stated speed for the M1A2 is considerably too slow.

One way to penetrate the essence of national design style is to ask what kind of trade-offs designers accepted. All engineers make choices among desired features of hardware; all pieces of military technology reflect those choices. A tank has three fundamental characteristics: protection, firepower, and mobility. Increase the amount of armour and one sacrifices the tank's ability to move quickly; put a small-bore, low-recoil cannon on it and one gains a great deal of mobility for a penalty in firepower; increase horsepower and pay a penalty in terms of the size of the tank (and hence protection) or how far it can go (and hence mobility).

Military technology also reflects processes of interaction. Tanks did not grow to be today's 60-ton monsters because of the growth of their power plants or guns. Developments in armour were to blame. Tank armour once consisted of rolled homogeneous steel. Today, it may consist of a variety of substances—exotic metals such as depleted uranium, composites that include alternating layers of metal and ceramics, and sandwiches of metal and high explosive. These changes reflect the development of ever more powerful antitank weapons—depleted uranium rods and so-called shaped charges (explosives configured to create a jet of hot metal that burns its way through armour). Even in peacetime, measure and countermeasure rule the choices designers make. These interactions create a kind of evolutionary process, by which a weapon system settles into its own 'ecological' niche. Birds and lizards evolve an amazing variety of counters to their predators, who in turn come up with a range of adaptations that enable them to find and devour their prey. So too with weapon systems. As in nature, interaction may yield odd outcomes, where one kind of highly sophisticated adaptation to a particular environment makes a platform utterly unsuited to a different battlefield. The first two generations of stealth aircraft, for example, evolved to avoid detection through the use of adroitly shaped surfaces that would disperse or absorb radar energy: they were difficult (not impossible) to detect using the radar technology of the time. Their odd shaping, however, made them slower and less manœuvrable than other aircraft; they have therefore become night-time-only systems that would be vulnerable to optical detection during the day.

In assessing military technology one should look at invisible technology as well. What gave the German tanks an edge over their French counterparts in the Second World War, for example, was not superior armour, guns, or engines, so much as a piece of technology barely noticed by outside observers—the radio (Stolfi 1970). Often, the most important elements of a military system are not the ones most evident to the casual observer, yet mastery of such technologies may weigh most in battle. American forces in the south-west Pacific in the Second World War struggled not only with the Japanese, but also with disease. The insecticide DDT, as much as any bomber or battleship, won the fight for New Guinea.

One should consider the role of systems technology and not just its parts. A novelist described a Second World War warship this way:

> "One way of thinking of the ship was as of some huge marine animal. Here on the bridge was the animal's brain, and radiating from it ran the nerves—the telephones and voice tubes—which carried the brain's decisions to the parts which were to execute them. The engine-room formed the muscles which actuated the tail—the propellers; and the guns were the teeth and claws of the animal. Up in the crow's nest above, and all round the bridge where the lookouts sat raking sea and sky with their binoculars, were the animal's eyes, seeking everywhere for enemies or prey, while the signal flags and wireless transmitter were the animal's voice, with which it could cry a warning to its fellows or scream for help."

(Forester 1943: 22–3)

As the war progressed, the brain of the ship vanished into its bowels, so to speak—becoming the combat information centre of modern vessels. But Forester's point was that the effectiveness of the ship rested not simply on the working of all the different technologies individually, but rather on their effectiveness as a whole. The very use of the term weapon *system* implies that the art of putting technologies together is more important than their individual excellence. In war, more than in most other activities, the whole can be far greater than the sum of its parts.

Our last concept is that of the technological edge. It is not always decisive, but it is almost always important. J. F. C. Fuller (1945: 18) once suggested that Napoleon himself would have succumbed to the semi-competent British general in the Crimea, Lord Raglan, simply because the latter's army had rifles, while the former had smoothbore muskets. It is only recently that the advanced powers have assumed that they would go to war with a decided technological edge over their opponents, and that this advantage would prove decisive. Technological superiority does not necessarily extend across the board. In the Persian Gulf War of 1991, for example, some Iraqi artillery pieces (their South African made G-5 howitzers) outranged Western counterparts such as the American Paladin system, by 6 kilometres or more (30 vs 24 km, to be precise)—much as Russian-made 122 mm guns outranged their American 155 mm counterparts in Vietnam.[2] The poorer, smaller, or weaker side may have some niche competencies that will surprise a richer and more powerful opponent. The technological edge may be dramatic (the quintessential case being the Dervish armies of the Khalifa crumpling under the fire of Lord Kitchener's Anglo-Egyptian infantry using the Henry-Martini rifle), or quite subtle—a matter of a few seconds' difference in the flight time of an air-to-air missile, or a few hundred yards in the effective range of a tank gun. The technological edge may have a psychological dimension that vanishes over time, as with Second World War-era German dive bombers with their unearthly wailing sirens, or American heliborne infantry in Vietnam appearing from the skies in remote jungles; or it may reflect fleeting disparities in commercial technology (e.g. commercial Global Positioning System navigation receivers purchased by Americans, but not Iraqis, in the Gulf War).

KEY POINTS

- There are a range of different theories about how military technology develops.
- Military technologies often reflect different national styles.
- Different national styles are determined by a variety of things, such as political assumptions, trade-offs between various features of hardware, processes of interaction, invisible technologies, systems technology, and the search for technological edge.

Mapping Military Technology

It can be difficult enough to understand military technology when it remains static: the authors of novels about the Napoleonic era war at sea, such as Patrick O'Brian or C. S. Forester, have a considerable challenge (which those two meet wonderfully well) in describing the complex technology of early nineteenth-century naval warfare. But the problem of understanding military technology is more difficult because it changes continuously. Indeed, since the middle of the nineteenth century, change in military technology has become a constant, through what Martin van Creveld has called 'the invention of invention'. The traditional picture of soldiers suspiciously rejecting new technology in favour of old standbys was always overdone: before the First World War, for example, the armies of Europe embraced the machine gun and the aeroplane. Their difficulty lay, and lies today, in recognizing what broader changes new technology may entail. For powerful institutional reasons, military organizations tend to fit new technologies into old intellectual and operational frameworks.

One question to ask in assessing technological change is whether what one is witnessing is a change in quantity or a change in quality. It is a more complicated question than it might appear. Marginal increases in speed, protection, mobility, or payload, to take just a few design parameters, are quantitative: they may have cumulative effects, but in and of themselves should not bring about radical changes in war. Sometimes, however, a seemingly quantitative change is, in fact, qualitative. Early firearms, for example, delivered rather less effective lethality than a good long bow; oil-fired ship engines offered moderate increases in speed over their coal-powered counterparts; and the first generation air-to-air missiles provided only marginal improvements over a well-aimed burst of cannon fire. All of these changes, however, foreshadowed tremendous upheavals in the conduct of war. Mastery of the long bow could take a lifetime. Mastery of the musket took a few months of drill, and its incidental qualities—the noise, smoke, and flash, none of which had direct effects on the enemy—made it a more fearful, that is, psychologically effective, weapon. Oil propulsion reduced the size of crews, increased the speed of ships, and, perhaps most importantly, made the world's oil fields prime strategic real estate. Air-to-air missiles improved far beyond the capability of mature aircraft cannon, to the point of engaging targets well beyond visual range.

Contemporary observers will often get it wrong. Military organizations (the US Navy in particular) had experimented with satellite-based navigation systems since the early 1960s (Friedman 2000). It took the experience of the Gulf War in 1991, however, to make average sailors, pilots, and soldiers realize that the Global Positioning System could transform all aspects of navigation from art to science, or rather mere technique. By contrast, the advent of nuclear weapons in the late 1940s and 1950s convinced some professionals that all military organizations would have to be radically restructured to accommodate the new weapons. As it turned out, however, only selected military organizations needed to adapt their tactics and structures to the new devices (Bacevich 1986). Military organizations and platforms do not change at a uniform rate. Some aspects of military technology change very little over the decades. Visit an aircraft carrier's deck, and one is struck by how little many procedures have changed in half a century. Steam catapults—themselves solid pieces of mid-twentieth-century engineering—loft jet aircraft off angled decks devised shortly after the Second World War. The crews, in multicoloured jerseys, each of which identifies their function, work pretty much as their fathers did during the Korean war. Inside, the Air Boss and his (or her) staff track the movement of aircraft using model aeroplanes on a large flat table; below decks illuminated glass grids show the status of all aircraft. There are important changes—more accurate and powerful bombs, far better intelligence flowing in, better aircraft—but the structure is remarkably durable. The same might be said of a battalion of paratroopers ready to drop on an airfield and seize it. Their aircraft, C-130s designed in the early 1950s and first fielded in 1956, are crammed with men carrying parachutes whose fundamental design goes back to the Second World War.[3] The process of training, loading, and deploying those men remains, in its essentials, the same.

Some military processes change to a considerably greater extent. A large desert armoured battle, for example, bears some resemblance to the clashes of the Second World War: masses of ponderous armoured beasts manœuvring over open ground, generating vast clouds of smoke and dust, swirling in a mêlée where the advantage goes to the quicker shot and calmer head. But much has changed, too. Today's armoured battle might take place at night, using thermal imaging devices that are in many ways better than optical sights even on a clear day. This is a far cry even from the night battles of the 1973 Yom Kippur war, in which Syrian tanks using crude infrared projectors attacked after daylight; for the modern armoured force, there is no important difference in visibility between day and night. The armour, gun power, and speed of the tanks today are much greater than during the Second World War, as is tank size. Those are important quantitative changes, but the biggest shift is in the accuracy of their weapons. A well-calibrated gun, with even a moderately competent crew (aided by laser range finders and ballistic computers) can score a first-round hit at a distance of several kilometres—a significant change in the way tank battles are fought.

Sometimes there are changes that fundamentally alter war fighting. The first night of an air operation, for example, is now completely different from what occurred during the Second World War, Korea, and Vietnam. In one or two nights a competent air force can shut down an enemy's air defence system, rather than wearing it out by a process of attritional struggle with defending fighter aircraft. Precision weapons—now ubiquitous in the arsenals of developed countries—mean that an initial attack can, in theory at least, prove paralysing. It is not the case that airpower can do more efficiently that which it did in the past—it can do things that it never could have done before. Thus, for example, with adequate intelligence and planning, a well-conducted air strike can cripple a nation's telecommunications system, in part by attacking targets (relay towers or switching centres) that previously were not susceptible to mass attack.

KEY POINTS

- One of the problems of understanding the role of military technologies is the constant process of change that takes place.
- One difficult issue concerns the relationship between qualitative and quantitative change.
- Another difficulty is that some technology is slow to have an effect, while some is much more immediate and radical in its impact.

The Revolution in Military Affairs Debate

When a set of changes comes together, the result (some soldiers and historians would argue) is a revolution. Normally, military technology merely evolves, at greater or lesser speeds, and unevenly. Occasionally, however, several developments will come together and yield a broader transformation. Thus, in the middle of the nineteenth century the combination of the telegraph (which allowed real-time links between civilian authority and military commanders, and between commanders in large military organizations), the railway (which permitted mass movements of troops and their sustenance during winter or while conducting sieges), and the rifle (which made infantry engagements lethal at greater ranges than ever before) transformed war. The mass conflicts of the wars of German unification and the American Civil War involved industrialized masses, and spelt the end of battles conducted in compressed periods of time and narrowly defined locations. They foreshadowed the slaughter of the First World War, as a few prescient observers noted.

Since the late 1970s, a number of observers have suggested that a revolution in military affairs is under way. Soviet writers—senior military officers, including the then Chief of the Soviet General Staff, Nikolai Ogarkov—suggested that modern conventional weapons would soon have the effectiveness of tactical nuclear weapons. Long-range sensors, including powerful radars mounted on aircraft, combined with precision weapons, would allow the detection and destruction of armoured units long before they ever approached the battlefield. Soviet military leaders believed that the United States, with its superior technological base, would drive these developments, and that their consequence would fall very much to the disadvantage of the Soviet Union, reliant as it was on waves of armoured forces that could move into Europe from their mobilization areas in the western USSR.

In the West, a number of technologists had similar, if less well-articulated, aspirations for weapon systems that would combine accuracy, range, and above all 'intelligence'—the ability to home in on, or even select, their own targets. It took the 1991 Gulf War to convince a broad spectrum of officers that very large changes in the conduct of war had occurred. The lopsidedness of that war, the undeniable effectiveness of precision weapons, and the emergence of a host of supporting military technologies (stealth, for example, which is actually a cluster of technologies) convinced many observers that warfare had changed fundamentally. The developments first noted in the Gulf War continued in a decade of smaller scale military engagements thereafter, including repeated American and British strikes against Iraqi targets, and NATO operations against Yugoslavia as a result of the wars in Bosnia in 1995 (Operation Deliberate Force) and in Kosovo in 1999 (Operation Allied Force). Attacking both by night and by day, and using primarily guided weapons, the United States and (to a lesser extent) its allies conducted operations with extraordinary accuracy and negligible combat losses. Similarly, the combination of special operations forces, unmanned aerial vehicles, and aircraft delivering precision weapons (and unguided ones for that matter) had a devastating effect on admittedly ragtag Taliban troops in Afghanistan in 2001. These and American regular ground and air forces occupied Iraq, and crushed the regime of Saddam Hussein, and its admittedly fragile and obsolescent military, in less than three weeks in 2003.

An adequate conceptual description of these changes, however, remained elusive. The Vice-Chairman of the American Joint Chiefs of Staff, Admiral William Owens, described what he termed 'the system of systems' as the ultimate potential of the new technologies, if not their actual achievement (Owens and Offley 2000). By integrating long-range, precision weapons with extensive intelligence, surveillance, and reconnaissance, and vastly improved capabilities for processing information and distributing it, he believed the United States could hope to detect and destroy any enemy target over swathes of the earth's surface as large as two hundred by two hundred miles. Some in the military scoffed at this as a technologist's fantasy, pointing to the persistence of what Carl von Clausewitz termed 'the fog of war' even in seemingly immaculate military operations against feeble opponents—the limited success of NATO aircraft in knocking out Serb tanks in 1999 being a case in point. Owens himself declared that enormous bureaucratic impediments—the persistence of individual service cultures, in particular—stood in the way of his dream being achieved.

In truth, the revolution in military affairs debate remains unsatisfying. Clearly, large changes are at work, but a mere recitation of new technologies does not describe the kinds of changes emerging in warfare. The military tests that have occurred thus far involved the wildly disproportionate forces of the United States and its allies against far smaller opponents. In 1999, for example, Yugoslavia's gross national product was barely a fifteenth the size of the American defence budget. The outcome of such ill-matched encounters could serve as indicators, perhaps, but not proof of a large change. It is possible that a revolution in military affairs has occurred, but it will require evidence gathered in a much larger conflict to become manifest. It is more likely that it would require the pressure of major great power competition in the arena of conventional armament to press modern armed forces to realize such changes to their fullest. At the moment, such competition does not exist, although in theory the rise of China in opposition to American dominance in the Pacific could provide the occasion for a real revolution to make itself known. One can, however, discern at least three broad features of the new technological era in warfare: the rise of quality over quantity, the speciation of military hardware, and the centrality of commercial military technology.

The rise of quality over quantity

Historians will describe the period extending from the French Revolution to at least the middle of the twentieth century as the era of mass warfare (e.g. already Howard 1975: 75 ff). During this time, the dominant form of military power was the mass army, recruited (in wartime, at least) by conscription, and uniformly equipped with the products of heavy industry. Those countries that could mobilize men and military production most effectively could generate the most military power—and this was true of the largest powers (like the Soviet Union) and the smallest (like Israel). Broadly speaking, the bigger the force the better—a far cry from the days of the eighteenth century when military authorities believed that armies could not operate beyond a certain optimal size, and when the way of war and contemporary economics dictated the protection of civil society from widespread compulsory military service.

The age of the mass army is over (see Moskos *et al.* 2000). The near-annihilation in 1991 of the Iraqi army, the world's fourth largest, marked the appearance of a world in which modestly obsolescent technology had become merely targets for more sophisticated weapons. Around the world, states abandoned compulsory military service and shrank the size of their armed forces, even in those countries (China and Turkey, for example) where they actually increased their defence expenditures substantially. Several converging developments produced these changes: the growing incompatibility between civil and military culture, the increased expense of military training and technology, and the vulnerabilities created by large forces. But nothing mattered more than the emerging importance of the technological edge in combat.

A simple *gedanken* experiment confirms this. Ask any group of field grade army officers which side they would prefer to command: an American armoured battalion task force of 54 M-1 tanks plus small numbers of infantry and other supporting arms, or an Iraqi Republican Guards division of over 300 moderate-quality T-72 tanks, with the full panoply of divisional artillery and support. They will choose, unanimously, the American armoured task force.[4] The combination of superior technology and better trained and led soldiers means that, in certain kinds of combat, force ratios hitherto thought utterly unacceptable—1 to 3, or even worse—could nonetheless yield victory to the seemingly hopelessly outnumbered side. To be sure, this observation may not apply equally to all forms of combat, or might not hold true in particular situations, but the broad truth remains: to a degree far greater than, say, during the Second World War, quality now trumps quantity. That quality, moreover, lies in the combination of manpower and technology. Superbly trained troops in mediocre tanks and aircraft might do well against mediocre troops in correspondingly magnificent weapon systems, but in the real world such match-ups rarely occur. The old systems of estimating military power no longer apply, be they the crude tabular comparisons of forces that appear in the newspapers or weekly news-magazines, or the seemingly scientific calculations of attrition-driven Pentagon models. The emergence of quality as the dominant feature in military power has rendered obsolete, if not absurd, today's systems of calculating relative military power.

The speciation of weapons

In the nineteenth century, and for most of the twentieth, the armed forces of the world shared similar weaponry. There have always been minor differences: even an early twentieth-century Mauser differed from a Lee Enfield or Lebel rifle. More important differences began to emerge in the First World War when, for example, the Allied states invested heavily in tanks, where the Germans did not; and certainly by the Second World War, when the United States and Great Britain developed heavy bombers that were imitated by neither their enemies nor their chief ally, the Soviet Union. The British, moreover, concentrated on aircraft optimized for night bombing, with heavy payloads and sophisticated night navigation, but little defensive ability, where the Americans concentrated on daylight bombing of industrial targets. Still, during the Second World War, and even during much of the cold war, basic weapon systems were similar. By the end of the twentieth century, however, weapons had evolved much like a sophisticated ecological system. This development had

BOX 7.2

Second World War Fighter Aircraft

	Spitfire	P-51	Bf-109	Zero
Date entered service	July 1938	April 1942	Sept. 1939	July 1940
Weight (fully loaded, lbs)	5,800	8,800	5,523	5,313
Range (miles)	395	950+	412	1,160
Speed (mph)	364	387	354	331
Armament	8 × 303 in. machine guns	4 × 20 mm cannon	2 × 7.92 mm machine guns 2 × 20 mm cannon	2 × 7.7 mm machine guns 2 × 20 mm cannon
Engine horsepower	1,030	1,150/1,590	1,100	940

Many aspects go into the performance of an aircraft: the statistics here are but a few of the key indicators of effectiveness—others include climb and turn rates, for example. But some anomalies here are suggestive. The Japanese extracted tremendous range out of the Zero, which they needed for operations in the Pacific region. They got that by good design—and by stripping out armour. The result was a highly manœuvrable but vulnerable aircraft that when hit was often destroyed. The P-51 was a hulking brute of an airplane; once the powerful Merlin engine was installed—a power plant with 50 per cent more capacity than its competitors—the Allies had a long-range fighter that could escort bombers to the heart of Germany or deliver bombs as well as cannon fire. More subtle differences (for example, the American and British preference for standardized weapons, as opposed to the mix of armaments on the Bf-109 and Zero) speak to national styles of weapons design, to include a strong priority on aerial firepower.

three parts: the evolution of the actual implements of destruction, the emergence of unique platforms, and the creation of larger systems of military technology.

An example of the first development is the British runway-attack munition JP-233. This system discharged 30 penetrating rockets and over 200 scattered mines from a low-flying Tornado fighter bomber. The Royal Air Force developed tactics and practised skills suited to its capabilities; when put to the test in the Gulf War, however, it proved nearly useless and indeed dangerous for pilots who had to fly low and straight over Iraqi runways. JP-233, an extremely expensive munition was, in truth, designed for a single scenario, that is, conventional conflict in Europe. Its purpose was to slow down a surge of Soviet fighter planes early in an East–West war by temporarily disabling Warsaw Pact airbases, allowing outnumbered NATO forces to gain air superiority over time. In Iraq, however, the numerical (not to mention the qualitative) balance was on the other side; Iraqi airbases were far larger than their Warsaw Pact counterparts, meaning that RAF pilots had to make longer (and hence more dangerous) runs over defended perimeters. Iraqi bases also had numerous runways and taxiways (unlike their Warsaw Pact counterparts) and could still service fighter aircraft—which, however, being outnumbered and outclassed, had very little inclination to take off!

The day of the simple high-explosive bomb is, if not over, close to it. Antitank missiles may carry not one but several warheads specifically designed to detonate layers of reactive armour and then to penetrate the sophisticated composite armour of tanks. A guided bomb may have a sophisticated nose that will not merely penetrate several layers of concrete and dirt, but actually count the number of floors it has penetrated before detonating (presumably) at the right one.

Military technology has diversified in another way. Whereas in the past all powers of the first rank had similar kinds of weapons systems, that is no longer the case. Only one country, the United States, can afford a large, stealthy, long-range bomber like the B-2. Relatively few countries can afford large sophisticated surface warships. Most countries, by contrast, can afford surface-to-surface ballistic missiles. This does not guarantee success to one side or the other, but it means that to the extent they still occur, arms races are more likely to be asymmetric. Thus Syria, which once hoped to achieve conventional parity with Israel in the late 1970s and early 1980s, has stopped trying to match the Israeli Air Force in the air. It relies, instead, on sophisticated Russian-made air defences and thousands of surface-to-surface missiles and rockets of varying types and quality.

A third form of military evolution has to do with the development not of weapons systems *per se*, but of meta-systems of extraordinary complexity. Networked sensors and command and control, such as the air operations centres that managed Allied air forces in the Gulf and Yugoslav Wars, are one example, but others will surely emerge. The US Navy's Cooperative Engagement Capability, which allows all the ships in a task force to share a common picture based on the sum of all data in the system, is a prototypical example. So too are the space command and control systems that allow military staffs to track most objects in close orbit, and to coordinate the movements of spacecraft. Increasingly, these systems reflect less a traditional system of military command and control—in which information flows up and decisions down—but a far less hierarchical sharing of information and with it a certain dilution of authority as traditionally understood.

Engineers use the term 'systems integration' to describe the art of putting together a complex of technologies to achieve a purpose. Not all countries excel at it: the United States and several European states have, as the triumph of their aerospace industries indicates. Japan has found it more difficult, while China and Russia have mixed records (Hughes 1998). Conventional military power rests, increasingly, on the ability of states to put together combinations of sensors and weapons and to make them function together in a fluid environment. Other forms of military power (terror or low-intensity warfare at one level, weapons of mass destruction at the other) do not demand these qualities.

The rise of commercial technology

Some percentage of military technology has always derived from the civilian sector. The famous Higgins boat of the Second World War, for example, which landed hundreds of thousands of Allied soldiers on beaches around the world, was a modification of a small craft originally designed for work in the Everglades swamps of Florida.[5] More broadly, civilian technologies have, from time to time, had an enormous effect on the conduct of war. The telegraph and the railway were, of course, both civilian technologies. Following the Second World War, however, to an unprecedented degree the armed forces of the developed world created vast research establishments operating on the cutting edge of technology; military inventions tended to spill over into the civilian realm more than the other way around. The transistor and modern jet engines, to take two radically different-sized technologies, emerged from military research and development. This held true at the beginning of the information age as well. The Internet originated in the United States Department of Defense's ARPANET—a system developed by the Advanced Research Projects Agency to enable the transmission of messages in the event of nuclear war. Similarly, space-based sensing emerged out of Western and Soviet efforts to exploit space for military purposes.

The information age is fundamentally different in this respect. Civilian technology, particularly in the area of software, leads military applications. The shift from supercomputers (once a prerogative chiefly of security institutions such as the National Security Agency, responsible for breaking the ciphers of foreign nations) to massive parallel processing, which used the linked power of many smaller computers to take on tasks hitherto reserved for much larger machines, is one example of a broader trend. Even when civilian technology does not yet lead military technology (in space-based sensing, for example) it is not very far behind: civilian satellites today can achieve resolutions (one metre or less) barely imaginable for their military counterparts only a decade or two ago.[6] Tourists looking for maps, satellite imagery, and GPS co-ordinates, as well as automated directions, can obtain them all—for free—with a tap on the keyboard of any computer connected to the internet. These trends will continue as vast sums of money for research and development—and with it talented scientists—turn to the civilian and away from the military sector. Information has no value without military technology to act on it, to be sure, but information, and the ability to process it, is the heart of modern conventional warfare.

These three trends—the rise of quality, the speciation of weapons, and the increased role of commercial technology—generally work to the benefit of developed open societies. They require a sophisticated industrial base for their manufacture, a skilled workforce for their maintenance, and, above all, flexible organizations for their intelligent use. These are qualities most likely to be found in democracies. As recently as a few decades ago, many thoughtful observers believed that democratic states stood at a near-ineradicable disadvantage *vis-à-vis* authoritarian or totalitarian counterparts, and indeed many of those weaknesses persist: the potential for indecision and volatility, indiscipline, and more recently, a pervasive sensitivity to casualties. Outweighing these and other weaknesses, however, are liberal democracies' strengths: their wealth (which makes military hardware affordable), their citizens' relative comfort with technological change, and fluid, egalitarian social relationships that breed a willingness to share rather than hoard information. For the moment, at any rate, the rise of the information technologies seem to ensure the conventional dominance of liberal democracies.

KEY POINTS

- On occasions in history several developments have come together to create a revolution in military affairs (RMA).
- Following the Gulf War in 1991, changes in accuracy, range, and intelligence led many to believe a new RMA was taking place.
- Recent conflicts between unequal adversaries make it difficult to discern if a real RMA has occurred.
- There are three main features of the new era in warfare; the importance of quality over quantity; the speciation of military hardware; and the increased role of the commercial technologies.

Asymmetric challenges

There is an apparent strategic paradox in the increasing technological edge of advanced, conventional powers who find themselves baffled or even defeated by irregular opponents. Israel's unsuccessful decade-long war (from 1991 to 2000, although preceded by skirmishes beforehand) with Hizbollah guerrillas in southern Lebanon is a dismaying example of how a vastly superior force, armed with high tech weapons, can find itself defeated by an adroit opponent who knows how to play on the sensitivity of a democracy to its own casualties, and on world concern for civilians caught in a crossfire. American forces in Iraq following the overthrow of the Saddam Hussein regime in 2003 were bedevilled by a robust insurgency that, through the use of IEDs (improvised explosive devices), suffered far heavier casualties than it did during the swift, violent, and overwhelming march to Baghdad. These experiences, like those of Russia in Chechnya in the preceding decade, have caused some to suggest that guerrilla or irregular warfare can reduce or eliminate the importance of technological advantage on the modern battlefield.

This is not quite true. Modern guerrillas and terrorists make use of cell phones, electronic triggering devices, and extremely sophisticated explosives for their bombs; those countering them use even more sophisticated forms of electronic sweeping and neutralization, unmanned aerial vehicles looking for those who plant IEDs, and precision guided missiles to destroy specific vehicles or rooms in a building. In the hard urban fight for Falluja in November 2004, US Army and Marine forces took casualties in the scores, not the hundreds that would have been characteristic of city fighting even during Vietnam. The Israelis experienced similarly low losses in their operations in the urban environment of the West Bank and Gaza in years preceding. Technology remains critical even in low-intensity conflict, and technological competitions—between bomb-maker and bomb-seeker, between guerrilla in ambush and convoy ready to fight its way through, between those protecting voting places and those seeking to prevent elections—persist.

The same might be said of another asymmetric strategy for technologically inferior powers—the resort to missile forces equipped with weapons of mass destruction, which offer non-democratic states the possibility of counterbalancing some, if not all, of the conventional predominance of their richer and more sophisticated opponents. Even the best missile defenses (and these have been deployed, and are being developed further) cannot guarantee a state's safety against such threats. And yet on the other hand, in the competition between advanced and less developed states, a real nuclear edge, if such thing exists, will go to the more developed state. In the ensuing stand-off, low-intensity conflict will flourish.

It is true, no doubt, that irregular warfare evens the playing field somewhat, but more in terms of strategy than operations. Guerrilla or terrorist strategies work when public opinion and political resolve are vulnerable to attrition of will. It is not clear that prosperous liberal democracies can always cope well with these threats. Democracy can wage conventional warfare and remain true to itself; it is far more difficult for it to battle terror and insurgency without resorting to strategies—to include extensive surveillance of its own citizens, population control, and even assassination—that are, in the long run, corrosive to its values. No society of this type, moreover, has yet had to absorb sudden, massive levels

of casualties comparable to those suffered by the inhabitants of Tokyo, Dresden, or Hiroshima at the end of the Second World War. How resilient rich, free countries will be in the face of such suffering remains to be seen.

On the other hand, thus far it turns out that advanced liberal states can use modern technology—from biometrics to robotics—to fight irregular opponents, and succeed. Israel's success in containing the second Palestinian intifada, reducing its own casualties, and inflicting crippling losses on the middle and senior levels of leadership of extremist organizations, speaks to the effectiveness of high technology, and the kind of will that can be evoked in the face of what society agrees is a serious threat. Similarly, the United States public has displayed remarkable persistence in a counter-insurgency operation in Iraq that has inflicted substantial casualties (more than 2,000 deaths as of 2006, and nearly seven times as many wounded), and that was, arguably, badly mismanaged in its early phases. In both cases, high technology played a role in limiting losses and achieving some successes.

KEY POINTS

- Superior conventional technology can be counterbalanced, to some extent, by asymmetric responses, such as irregular warfare and the threat of weapons of mass destruction.
- High technology, however, continues to play a role in conflicts fought out in this sphere.
- A critical question, in both cases, concerns societal willingness to persist in such conflicts.

Challenges of the New Technology

The asymmetric threat to the dominance of the new military technologies may take some time to make itself fully felt. Meanwhile, it is difficult enough for modern militaries to cope with the challenges posed by the information revolution. One difficulty has to do with personnel issues. Industrial age militaries could compete fairly easily with private enterprise because, at some level, they resembled it. A caste system resting on soldiers, noncommissioned officers, and officers mirrored a civilian stratification of workers, foremen, and managers. Compensation and deference structures were similar, although room could be made in the military, as in the civilian world, for more highly paid technical experts.

In the information age, the similarities between military and civilian organizations have broken down. Military organizations remain more hierarchical than many of their civilian counterparts, but more importantly, they find it increasingly difficult to obtain the human resources they need. A software engineer in the civilian sector is a highly paid, fairly autonomous employee, working with relatively little supervision. It has become acutely difficult for armed forces to recruit (and more importantly, retain) skilled men and women in these fields. Similarly, talented and aggressive young officers are far more aware than ever before of the possibilities open to them outside the military. Retaining their services in an age of economic opportunity is difficult not merely because of compensation inequities—those have always existed—but because the civilian sector can often offer far more opportunity for change, autonomy, and unfettered responsibility.

The information technologies have other, perhaps more subtle effects on the conduct of war. As a general rule, the greater the flow of information, the more possibility for centralized control. During the Second World War, for example, the Royal Navy and then the United States centralized anti-submarine warfare in shore-based organizations that exploited reliable long-range radio communications and critically important advances in intelligence gathering. Such a development was very much the exception, however. Today, videoconferencing and the electronic transmission of data mean that generals in national capitals can exercise close supervision over their subordinates. This effect exists throughout the military hierarchy: the challenge for mid-level and senior leaders has become one of controlling the instinctive desire to take charge of a more junior officer's problems. That impulse has become all the greater the more politically visible military action has become: when the result of a botched operation shows up immediately on CNN and a hundred websites, the inclination of higher authority to exercise the control that technology makes possible becomes all the greater.

Warfare often now occurs under the watchful eyes of the video camera and satellite uplink. In the Somalia intervention of the early 1990s, for example, American naval commandos (SEALs) slipped ashore (on 8 December 1992) in advance of a larger force, only to find a reception party of journalists awaiting them, brilliant lights blinding the wary sailors. There are exceptions: the Russians excluded the press from much of the second Chechen war, and the Rwanda massacres occurred before journalists could cover them adequately. The Arab–Israeli conflict, however, which resumed in 2000 with a Palestinian insurrection, may prove to be more the norm: rock throwing and shooting watched by (indeed, often staged for) journalists. Propaganda, always an adjunct of war, became a central element in the Arab–Israeli struggle, and both sides found themselves structuring military action with reference not only to the traditional considerations of geography and tactics, but also to the consideration of publicity. Adults manœuvred Palestinian stone-throwing children into positions for optimal camera shots of 14-year-olds with rocks up against 19-year-olds with rifles. Meanwhile, after some abysmal failures (helicopter gunships blowing up empty houses), the Israelis reverted to sniper work and night-time kidnappings and assassinations precisely to avoid teams of journalists. Both sides created their own, and wrecked their opponents', websites as the conflict extended into cyberspace. The real and the virtual battlefields had become a complex and inextricable whole. This development persisted in the Iraq War, which took a much grislier turn. Insurgent strategy included kidnappings and gruesome beheadings, which were the stuff not only of broadcasts on Arab-language television, but of film clips on jihadi websites, seeking to intimidate opponents, discourage foreign development aid, and enlist new supporters. To some extent, moreover, it worked.

KEY POINTS

- The civilian sector poses a major challenge to maintaining military expertise.
- Information technology may lead to greater centralization of military control.
- Media coverage of conflicts pose challenges for military and political leaders.

The Future of Military Technology

Military technology has contributed to a far more complicated environment for war than that of previous centuries. To the extent one can generalize about its effects, one would have to say that where the dominant forms of war in the past were few, today they are many. The challenges for armed forces are correspondingly immense.

Nor have the changes wrought by the new technologies come to an end. The increasingly easy access by countries to space, and their reliance on space for routine communications, navigation, and information gathering, seems almost certain to propel war into the heavens. For the moment, no country seems to have placed, or at least used, weapons in space that can disable or destroy either other satellites or targets on earth. Similarly, countries have experimented with, but not yet used, technologies on earth capable of affecting space-based systems. Technology, however, clearly permits this, in the form of lasers that can blind satellites, or mere lumps of metal that can hurtle from space to earth delivering enormous amounts of kinetic energy against their targets hundreds of miles below. The opening of space to full-fledged warfare would be as large a change as the opening of the air was during the First World War. New organizations, new operational conditions, new incentives to strike first, new ways of war, will blossom overnight.

Warfare also appears to be moving to cyberspace. Thus far, despite persistent stories about mischievous teenagers, clever criminals, or nefarious agents creating havoc with computer systems, there does not seem to be evidence of really large-scale damage done by cyber-attack—no massive loss of life or even money attributable to cyber-attack alone. It remains a theoretical possibility, however. As with the opening up of space, the realization of the potential for war in cyberspace would elicit an efflorescence of organizations, concepts, and patterns of conflict parallel to, but very different from, those of conventional warfare.

A third sort of change already under way consists of advances in manufacturing, particularly in what are known as the nanotechnologies, robotics, and artificial intelligence. While it is highly unlikely that human beings will ever leave the battlefield (if only because the battlefield will surely come to them), more of the dangerous work may devolve upon small autonomous, intelligent machines that creep or fly, or merely sit and wait, classifying and attacking opponents. Animated, superintelligent minefields transposed on land might make movement or manœuvre by conventional forces extremely difficult. More importantly, the creation of such machines will mean that humans have gradually begun to cede much of their ability to make decisions to silicon chips. It is a process already well under way in some areas—modern aircraft, for example, are so intrinsically unstable that an automatic system, rather than a human being, must adjust their trim.

In all these cases, the most interesting and important consequences of technological change will probably flow from its effect on how human beings think about and conduct war: how they conceive of military action, how they assign responsibility, how they calculate military effects, how they attempt to harmonize means and ends. But a fourth set of changes, perhaps the most profound of all, looms larger yet. The biological sciences increasingly make it possible to change the nature of human beings themselves (Fukuyama 1999). The intriguing theoretical possibility of Greek philosophers has become, in our age, the challenge of scientific researchers. One can scarcely doubt that an Adolf Hitler, or for that matter a Saddam Hussein, would have availed himself of the resources of biotechnology to breed new kinds of human beings—super-soldiers, for one thing, insensitive to fear and truly loyal to the death—who could serve his purposes. Our common understanding of war rests on some of its deeply human features, which have not changed since the days of Homer or Thucydides.[7] This is so, however, only because the same species, *homo sapiens*, has continued to wage it. If—when?—humans are replaced by a variety of creatures, some subhuman, and others, in some respects, superhuman, war itself will have become an activity as different from traditional human conflict as are the murderous struggles between competing anthills or the stalking of herds of deer by packs of wolves.

QUESTIONS

1. Take a representative military technology such as the tank. Using several examples, how would you characterize the national style embedded in the design of these armoured vehicles?
2. What is stealth technology? Does the concept of interaction apply to it?
3. In what cases does military technology require high levels of technical expertise and education, and in what cases does it actually reduce or even eliminate such a requirement?
4. What are some of the military technologies that only the United States has available to it? Other great powers? Smaller states? Non-state actors?
5. What are some examples of 'the technological edge'? How fragile are such leads by one state or another?
6. Is cyberwarfare really 'warfare'? Are there other metaphors that might explain it better?
7. What implications are there if warfare extends to space—will it impact more on commercial or military technology?
8. What are some of the technologies most useful to the conduct of irregular warfare, to include guerrilla and terror operations?
9. Are democracies better placed than authoritarian/totalitarian regimes to adapt to the changing nature and problems of technological warfare?

FURTHER READING

- **John D. Bergen, *Military Communications: A Test for Technology* (Washington, DC: Center of Military History, 1986), chs. 16–17, pp. 367–408.** Describes an interesting competition in communication technology and electronic warfare between an extremely sophisticated state (the USA) and a considerably more backward one (North Vietnam) in which the more developed society did not necessarily do well.
- **Alan Beyerchen, 'From Radio to Radar: Interwar Military Adaptation to Technological Change in Germany, the United Kingdom, and the United States', in Williamson Murray and Allan R. Millett (eds.), *Military Innovation in the Interwar Period* (Cambridge: Cambridge University Press, 1996).** A good example of how national style appears even in the electronic realm.
- **Winston Churchill, *The World Crisis, 1911–1914* (New York: Charles Scribner's Sons, 1926), ch. 6, 'The Romance of Design', pp. 125–49.** Brilliantly describes some of these challenges from the point of view of a decision-maker.
- **Arthur C. Clarke, 'Superiority', in *Expedition to Earth* (New York: Harcourt, Brace & World, 1970), pp. 92–104.** A science fiction story with a whimsical but wise warning on the dangers of becoming too sophisticated.
- **Martin van Creveld, *Technology and War from 2000 B.C. to the Present* (New York: Free Press, 1989).** Considerably more up to date than Fuller 1945.
- **J. F. C. Fuller, *Armament and History; A Study of the Influence of Armament on History from the Dawn of Classical Warfare to the Second World War* (New York: Charles Scribner's Sons, 1945).** Remains an excellent short treatment of the relationship between technology, tactics, organization, and strategy.
- **Wayne Hughes, *Fleet Tactics: Theory and Practice* (Annapolis, MD.: Naval Institute Press, 1986).** A thoughtful treatment of the role of technology in warfare.
- **Henry Petroski, *To Engineer is Human: The Role of Failure in Successful Design* (New York: Random House, 1982).**

—— *The Evolution of Useful Things* (New York: Vintage Books, 1992).

- **George Raudzens, 'War-Winning Weapons: The Measurement of Technological Determinism in Military History', *Journal of Military History*, Vol. 54 (Oct. 1990), 403–33.** A sceptical view of technology's importance.

Visit the Online Resource Centre that accompanies this book for lots of interesting additional material http://www.oxfordtextbooks.co.uk/orc/baylis_strategy2e/.