
**THE CHARACTERISTICS OF REVOLUTIONS
IN MILITARY AFFAIRS**

Technology-driven changes in military operations are not recent phenomena. Indeed, technological developments have been bringing about profound changes in the nature of warfare since the dawn of history.¹ Brodie (1973), Dupuy (1984), and van Creveld (1989) provide overviews of the historical panorama of military technology and its impact on warfare over the last (roughly) 4000 years, from the earliest developments (e.g., the chariot) to the most recent (e.g., nuclear weapons).

Beginning with the Soviet focus on the so-called military-technical revolution² and continuing with the work initiated by the Office of Net Assessment on the current revolution in military affairs,³ considerable attention has been paid to the sometimes revolutionary nature of advances in military technology, with particular focus on events in

¹A rich literature of the history of military technology describes this process. Van Creveld (1989) includes a bibliographical essay reviewing this literature, with numerous references.

²In 1984, Marshal Nikolai V. Ogarkov and other Soviet military thinkers began to stress that the emergence of advanced, nonnuclear technologies was engendering a new military-technical revolution in military affairs. See FitzGerald (1987) for an overview of Soviet thought on this subject.

³See Marshall (1993 and 1995) for original statements of the views of Andrew Marshall, the Director of the Office of the Secretary of Defense (OSD) Office of Net Assessment, regarding the current revolution in military affairs. Ricks (1994) contains an early published discussion of these views.

the 20th century. This has led to a resurgence of writing on the subject.⁴

We use these two historical records—of the long sweep of military technology and of the military revolutions in the 20th century—as our point of departure in describing the characteristics of RMAs.

WHAT IS AN RMA?

Much has been written recently regarding the current RMA, which is often viewed as

a military technical revolution combining [technical advances in] surveillance, C3I [command, control, communications, and intelligence] and precision munitions [with new] operational concepts, including information warfare, continuous and rapid joint operations (faster than the adversary), and holding the entire theater at risk (i.e., no sanctuary for the enemy, even deep in his own battlespace).⁵

A number of people have written regarding this RMA, including Kendall (1992), Marshall (1993 and 1995), Mazarr et al. (1993), Mazarr (1994), Krepinevich (1994 and 1995), Libicki and Hazlett (1994), Gray (1995), Barnett (1996), Libicki (1996 and 1999), Blaker (1997), Buchan (1998), and Davis et al. (1998).⁶ This literature well describes the elements of the current RMA, but does not shed much light on the characteristics of RMAs in general. That is, it does not address questions such as: How does one describe generically what constitutes an RMA? What are the defining characteristics of an RMA? To answer these questions, we must turn to the historical record of technology-driven changes in military operations.

Based on the historical record, it appears that the defining characteristic of an RMA can be stated as follows:

⁴See Krepinevich (1994), Murray and Watts (1995), Gray (1995), Bartlett et al. (1996), Libicki (1996), Murray and Millet (1996), and Blaker (1997) for a sampling of this recent literature.

⁵See McKendree (1996).

⁶The various DoD science boards have also discussed the current RMA, not always by name. For example, see SAB (1995), DSB (1996), and NSB (1997).

An RMA involves a paradigm shift in the nature and conduct of military operations

- which either *renders obsolete or irrelevant* one or more *core competencies* of a dominant player,
- or creates one or more new core competencies, in some new dimension of warfare,
- or both.

There are a number of key terms in this definition:

- *Paradigm.* An accepted model that serves as the basic pattern for a segment of military operations.⁷ For example, opposing infantry units arranged in orderly formations maneuvering in the open to engage each other at close quarters, with supporting artillery fire, was the operational paradigm for land combat during the Napoleonic Wars. Opposing warships arranged in line-of-battle on parallel courses and engaging with gunfire was the operational paradigm for naval fleet engagements during those same wars, as well as during the First World War 100 years later.
- *Core competency.* A fundamental ability that provides the foundation for a set of military capabilities. For example, the ability to detect vehicular targets from the air and attack them with precision weapons is today a core competency of the U.S. Air Force. In the period between World War I and II, the ability to deliver accurate naval gunfire at ranges upwards of 20 miles was a core competency of the surface combat units of the U.S. Navy. In the 13th and 14th centuries, the ability of a longbowman to put an arrow accurately through the chain mail armor of a knight on horseback or a man-at-arms on the ground at ranges of 250–300 yards was a core competency of the English archers.⁸

⁷Paradigms also play a central role in other areas of human endeavor. For example, Kuhn (1970) discusses the role of paradigms and paradigm shifts in science. Likewise, Barker (1992) and Grove (1996) discuss the role of paradigms and paradigm shifts in business. Grove uses the term “strategic inflection point” rather than “paradigm shift” to denote the phenomenon, but the meaning is the same.

⁸Dupuy (1984, pp. 81–84) and Burke (1978, pp. 59–62) discuss the capabilities of the English longbowmen.

- *Dominant player.* A military organization that possesses a dominating set of capabilities in an area of military operations. For example, today the U.S. Air Force is the dominant player in air-to-air combat and air-to-ground attack. At the end of World War II, the carrier force of the U.S. Navy was the dominant player in naval warfare. At the end of World War I, the battle fleets (e.g., the battleship and battle cruiser forces) of the British Navy and the U.S. Navy were the dominant players in naval surface warfare. Going back further in history, during the Middle Ages the armored cavalry (i.e., knights on horseback) was the dominant player in land warfare in Europe. Even further back, in Roman times the Roman legion was the dominant player in land warfare throughout the Roman Empire.
- *Dimension of warfare.* The dimension on which warfare is conducted, the first and most ancient of which was the land surface of the earth (land warfare). The second and almost as ancient dimension on which warfare was conducted was the water surface of the earth (naval warfare). In the 20th century several new dimensions were added: the underwater portions of the oceans (undersea warfare), the air above the earth's surface (air warfare), and the homelands of the combatants (strategic warfare and intercontinental warfare). Another dimension much talked about since the Second World War but in which actual combat has not yet occurred is the region outside the earth's atmosphere (space warfare). As the information revolution continues, there is increasing discussion of cyberspace as still another dimension of warfare (information warfare).⁹
- *Paradigm shift.* A profound change in the fundamental model underlying a segment of military operations. For example, the carrier warfare paradigm, in which opposing naval forces engaged each other at 100- to 200-mile distances without ever coming within naval gunfire range, represented a profound change in the basic model underlying naval warfare. It rendered obsolete the core (naval gunfire) competency of the hitherto

⁹See Toffler (1993), Molander et al. (1996), and Arquilla and Ronfeldt (1997) for three views of this newest dimension of warfare.

dominant battleship fleets, and was therefore an RMA.¹⁰ The blitzkrieg paradigm, in which highly mobile armored forces broke through enemy lines and rapidly penetrated to the rear, represented a profound change in the basic model underlying land warfare. It rendered obsolete the core competency of the hitherto dominant infantry and artillery forces for static defenses of prepared positions, and was therefore an RMA.¹¹ The nuclear-warhead-tipped intercontinental ballistic missile (ICBM) created a new core competency (an overwhelming, virtually unstoppable ability to destroy cities and other large-scale targets in the homeland of an opponent thousands of miles away) in a new dimension of warfare (intercontinental strategic warfare), and was therefore an RMA.

If a development in military technology does not either render obsolete a core competency of a dominant player or create a new core competency, it is not an RMA. If it does, it is.¹² Table 2.1 gives a few illustrative examples of developments in military technology that satisfy this criteria.

OTHER NOTABLE CHARACTERISTICS OF RMAs

Based on the historical record, other notable characteristics of RMAs are:

- *RMAs are rarely brought about by dominant players.* For example, during the period between the First and Second World Wars, the French and British infantry and artillery forces, the dominant

¹⁰The Battle of the Coral Sea (1942) was the first engagement in which this new paradigm played a dominating role. See Morison (1963), pp. 140–147.

¹¹There are many descriptions of the development and impact of the blitzkrieg paradigm. Guderian (1952) provides a subjective, firsthand view; Corum (1992) provides a more objective, balanced presentation.

¹²Krepinevich (1994) has proposed a logically similar definition of an RMA: “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.” We prefer our wording because of the emphasis it places on *changes in core competencies* as central to the RMA process.

Table 2.1
RMA: SOME ILLUSTRATIVE EXAMPLES

RMA	Nature of Paradigm Shift	Core Competency Affected	Dominant Player Affected
Carrier warfare	Created new operational and tactical-level model for naval warfare	Accurate naval gunfire of battleship fleets (rendered obsolete)	Battleship fleets (U.S. and British)
Blitzkrieg	Created new operational and tactical-level model for land warfare	Static defense of prepared positions by infantry and artillery (rendered irrelevant)	French army
ICBM	Created new dimension of warfare (intercontinental strategic warfare)	Long-range, accurate delivery of high-yield nuclear weapons (a new core competency)	
Machine gun	Created new tactical-level model for land warfare	Ability to maneuver massed infantry forces in the open (rendered obsolete)	All armies employing massed infantry forces in the open
Longbow	Created new tactical-level model for land warfare	Man-to-man combat capability of knights on horseback (rendered obsolete)	French armored cavalry

European players in land warfare at the end of World War I, did not develop the blitzkrieg concept of tank warfare, and the British navy, one of the dominant players in sea warfare, did not develop the concept of carrier warfare.¹³

¹³On the other hand, the U.S. Navy, one of the two dominant naval powers in the world at the end of World War I (along with the British navy), did bring about the carrier warfare RMA in the 1920s and 1930s. This is one of the few historical cases (known to the author) of a dominant player developing an RMA. It may tell us something about what it takes for a dominant player (like today's U.S. military) to be successful in transforming its military forces by carrying out its own RMA. For this reason, we will come back to this example in Chapter Six.

The carrier warfare RMA was developed independently by the Japanese navy during the same period. Little is available in English regarding the Japanese development of

- *RMA*s frequently bestow an enormous and immediate military advantage on the first nation to exploit them in combat. A few of many examples are the use of the longbow by the English against the French at Crecy in 1346,¹⁴ the use of the machine gun by the British against the Zulus in 1879 (we discuss this further below), the use of the blitzkrieg by the German army against the Poles in 1939 and the British and French in 1940, and, most recently, the use of stealth aircraft and precision-guided munitions by the United States against the Iraqis in 1991.
- *RMA*s are often adopted and fully exploited first by someone other than the nation inventing the new technology. For example, even though the key inventors of the machine gun were all Americans (William Browning, Richard Gatling, Isaac Lewis, and Hiram Maxim),¹⁵ machine guns were first used in a decisive fashion by European armies against native forces in Africa in the 1870s–1890s.¹⁶ The American army did not begin buying them in quantity and actively incorporate them into its tactical doctrine until many years later,¹⁷ after they were employed by the German army in September 1914 to stop the Allied advance at the Chemin des Dames ridge on the river Aisne.¹⁸ Similarly, the British invented the tank. Although they first employed it in combat during the Battle of the Somme on September 15, 1916 and later at the Battle of Cambrai on November 20, 1917, they

carrier aviation. Also, the Japanese navy was not a dominant player at the end of World War I, when its development of carrier aviation began. For these reasons, we do not discuss the Japanese experience in any detail in this report.

¹⁴The English had developed the technology of the longbow and operational concepts for its use in combat during a long series of civil wars within Britain, but the French had never seen it employed in combat. See Churchill (1958), pp. 332–351.

¹⁵See Ellis (1975).

¹⁶One of the first engagements in which machine guns played a decisive role was the Battle of Ulundi, in Natal in 1879, in which a British force equipped with four Gatling guns defeated the Zulu army. (Earlier the same year, a similar size British force without Gatling guns had been virtually wiped out by the same Zulu army at the Battle of Isandhlwana.) See Ellis (1975), pp. 82–84.

¹⁷It is a little known fact that General George Armstrong Custer's Seventh Cavalry possessed four Gatling guns. Custer left them in garrison when he departed on the campaign that led to Little Big Horn in 1876, since he felt they did not have tactical value (Ellis, 1975, p. 74).

¹⁸See Ellis (1975), p. 119 and p. 124. The German employment of machine guns from dug-in positions in this battle marked the beginning of World War I trench warfare.

did not understand how to fully exploit its capabilities. This was first shown by the Germans in 1939–1940.¹⁹ Likewise, in 1914 the British conducted the first carrier air raid in history, years before any other navy had operational carriers or carrier-based aircraft. However, they did not develop the RMA of carrier warfare, the American and Japanese navies did, as they demonstrated in the four major carrier battles of 1942.²⁰

- *RMA*s are not always technology-driven. For example, American combat tactics during the Revolutionary War (i.e., engaging an opponent from behind cover rather than in formation out in the open) brought about a revolutionary change in land combat without any change in the weapon technologies involved.
- *Technology-driven RMA*s are usually brought about by combinations of technologies, rather than individual technologies. More precisely, technology-driven RMA
s are usually brought about by weapons or systems exploiting combinations of technologies. Examples include the blitzkrieg, which was enabled by the combination of three technologies—the tank, the two-way tactical radio, and the dive bomber; and the ICBM, which was enabled by the combination of three technologies—long-range ballistic missiles, lightweight fusion warheads, and highly accurate inertial guidance.
- *Not all technology-driven RMA*s involve weapons. For example, the coming of the railroad to Europe and America in the 1830s–1850s led to a revolution in strategic mobility. This was first demonstrated by the French when they moved 250,000 men at heretofore unheard-of speed to the front in northern Italy to engage the Austrians during the War of 1859. It was later demonstrated (by both sides) on numerous occasions in the 1860s dur-

¹⁹ See Macksey (1975), Corum (1992), and Murray and Watts (1995) for discussion of the invention of the tank and its subsequent exploitation in the blitzkrieg concept.

²⁰The battles of the Coral Sea, Midway, the Eastern Solomons, and the Santa Cruz Islands (see Morison, 1963, pp. 140–163, 177–182, and 190–196). See Murray and Watts (1995, pp. 61–84) and Watts and Murray (1996, pp. 383–405) for the steps that led to the carrier warfare RMA, why the Americans “got it,” and why the British did not.

ing the American Civil War, and (particularly by the Germans) in 1870 during the Franco-Prussian War.²¹

- *All successful technology-driven RMAs appear to have three components: technology, doctrine, and organization.* Technology, even when developed into a revolutionary weapon or system, is not enough to produce an RMA. It must be combined with doctrine (i.e., an agreed-upon concept for the employment of the new weapon or system)²² and organization (i.e., a military force structure crafted to exploit the new weapon or system). For example, the blitzkrieg RMA resulted from the combination of the tank, two-way radio, and dive-bomber technologies, an operational concept in which highly mobile armored forces broke through enemy lines and rapidly penetrated to the rear, and a force structure (the panzer division) that concentrated the available tanks into a few specialized divisions.²³ The carrier aviation RMA resulted from the combination of technologies enabling military aircraft to take off and land on carrier decks; the operational concept allowed carrier aircraft to engage an opposing naval force at distances well beyond naval gunfire range and concentrate their attack on the opposing carriers. The force structure (the carrier task force) was built around the aircraft carrier and its planes.²⁴
- *There are probably as many “failed” RMAs as successful RMAs.* Some comparatively recent examples include the nuclear-

²¹See Brodie (1973, pp. 148–151) and van Creveld (1989, pp. 158–159).

²²Dupuy (1966) defines doctrine as “Principles, policies, and concepts which are combined into an integrated system for the purpose of governing all components of a military force in combat, and assuring consistent, coordinated employment of these components.” Doctrine normally includes concepts of operation, tactics, and, at its fullest, principles of strategy.

²³In contrast, the French, who had more (and better) tanks in 1940 than did the Germans, spread them out more or less equally throughout all the divisions of the French army (the wrong force structure) and used them as mobile fire support to the infantry (the wrong doctrine). During the 1920s and 1930s, the U.S. Army also viewed tanks primarily as infantry support weapons (the wrong doctrine); this led them to develop tanks with low-velocity guns (the wrong system), which were significantly inferior to the German tanks (with high-velocity guns) they faced in World War II. (See Johnson, 1990 and 1998.)

²⁴Dupuy (1984) discusses the critical role that the marriage of new weapons and new doctrine plays in the creation of an RMA.

powered military aircraft, the electromagnetic gun, and the thus-far unfruitful attempts to develop high-energy laser (HEL) weapons for use in military combat.²⁵ (We will come back to the subject of failed RMAs in Chapter Three.)

- *RMAs often take a long time to come to fruition.* There are many examples of this. The U.S. Navy began experimenting with aircraft in 1910; it took them almost three decades to fully develop the carrier warfare RMA.²⁶ Similarly, the German army began experimenting with tanks in the early 1920s; it took them almost two decades to create the blitzkrieg.²⁷ Further back in time, although all of the major technology developments embodied in the machine gun were essentially completed by the 1870s, it did not come to fruition as an RMA in European warfare until September 1914, some 40 years later.²⁸ Even further back in time, the English developed the technology of the longbow and operational concepts for its use in combat over almost a century of civil wars in Britain, before springing it on the French at Crecy in 1346.²⁹ So the “revolution” in revolutions in military affairs does not mean the change will occur rapidly—sometimes it will, often it won’t—but ultimately it will be profound.^{30,31}

²⁵See JDR (1986) for discussions of the evolution of HEL application thinking as of the mid-1980s. See APS (1987) for an assessment of the ballistic missile defense applications of HELs. Thus far, all of these attempts to develop militarily useful HEL weapons have been unsuccessful. However, the jury is still out; the latest application focus is on airborne HELs as an antitheater ballistic (ATBM) weapon. (See Aviation Week, 1996.)

²⁶We discuss the U.S. Navy’s development of the carrier warfare RMA more fully in Chapter Six.

²⁷See Guderian (1952), Macksey (1975), and Corum (1992).

²⁸See Ellis (1975).

²⁹See Churchill (1958), pp. 332–351.

³⁰Andrew Marshall (1995) makes this same point in his 1995 writing on RMAs, in which he says: “The term ‘revolution’ is not meant to insist that the change will be rapid—indeed past revolutions have unfolded over a period of decades—but only that the change will be profound, that the new methods of warfare will be far more powerful than the old.”

³¹Some RMAs do happen quickly, however. The best recent example may be the atomic bomb, which was developed and employed over a period of only four years. See Rhodes (1986).

- *The military utility of an RMA is frequently controversial and in doubt up until the moment it is proven in battle.* The British did not begin to realize the combat value of the machine gun until they used it with devastating force against the Zulus at Ulundi in 1879. Many British and French generals continued to seriously doubt the value of machine guns in a European war up until the Germans employed them to stop the Allied advance in September 1914.³² Not only most French and British generals but many German generals, including some in the German high command, doubted the value of the blitzkrieg up until the moment Guderian broke through at Sedan on May 13–14, 1940, and were vehement in expressing their doubts. Some French, British, and German generals continued to doubt it for days thereafter, even after Guderian reached the English Channel on May 20.³³ Many American admirals seriously doubted the power of carrier aviation up until the battle of Midway in June 1942.³⁴

LESSONS FROM THE BUSINESS WORLD REGARDING PARADIGM SHIFTS

Paradigm shifts are not limited to the military arena. They occur in the business world as well, where they have become a much-studied phenomenon.³⁵ A clear message from the business literature regarding product and process innovation is that product revolutions—the business world’s version of paradigm shifts—are rarely brought about by dominant players. According to Utterback (1994):

Discontinuous innovations that destroy established core competencies . . . almost always come from outside the industry (23 of 29 cases, with 4 from inside and 2 inconclusive).³⁶

³²See Ellis (1975).

³³See Guderian (1952), Macksey (1975), Liddell Hart (1979), and Corum (1992).

³⁴See Turnbull and Lord (1949).

³⁵See Barker (1992), Utterback (1994), Grove (1996), and Christensen (1997) for four recent examples of this literature. (Grove uses the term “strategic inflection point” and Christensen uses the term “disruptive technological change” to denote the phenomenon, rather than “paradigm shift,” but their meanings are the same.)

³⁶Utterback (1994, p. 208).

The following list is illustrative:³⁷

- Electric typewriters did not come from a major typewriter manufacturer.
- Ballpoint pens did not come from the pen industry.
- Levi's did not come up with designer jeans for women.
- Semiconductors did not come from the vacuum tube industry.
- Radial tires did not come from a major tire maker.
- Personal computers did not come from a major computer manufacturer.
- Wine coolers came from neither the wine nor soda industries.
- Disposable diapers did not come from the diaper services.

The typical impact of these “discontinuous innovations” on dominant players in the business world is stated by Bower and Christensen:

One of the most consistent patterns in business is the failure of leading companies to stay at the top of their industries when technologies or markets change.³⁸

Or in the words of Grove:

when a strategic inflection point sweeps through the industry, the more successful a participant was in the old industry structure, the more threatened it is by change and the more reluctant it is to adapt to it.³⁹

The historical message is clear: in neither military nor business affairs are “revolutions” (i.e., paradigm shifts that destroy core competencies) often brought about by dominant players.

³⁷Private communication from Samuel Gardiner.

³⁸See Bower and Christensen (1995).

³⁹See Grove (1996), p. 50.

THE RELATIONSHIP BETWEEN BREAKTHROUGH TECHNOLOGIES AND RMAs

What is the relationship between breakthrough technologies and RMAs? As our previous discussion shows, technology-driven RMAs are brought about by weapons or systems exploiting combinations of technologies, combined with supporting doctrine and organization. Technology alone, without accompanying doctrine and organization, cannot produce an RMA.

Use of the term “breakthrough technologies,” therefore, focuses on one of the *inputs* to the breakthrough process; use of the term “RMA” focuses on the *output* from that process. This is the essence of the relationship between breakthrough technologies and RMAs.

We discuss the process that leads from breakthrough technologies to RMAs in Chapter Three.

IS THE CURRENT MILITARY-TECHNICAL REVOLUTION A TRUE RMA?

There is another interesting question regarding RMAs: Is the current military-technical revolution—called by some “the RMA”—a true RMA? Based on our definition, it is too soon to tell. For it to be a true RMA, it must render obsolete or irrelevant one or more core competencies of a dominant player, or create one or more new core competencies in a new dimension of warfare. This has not yet happened.

But it could happen. For example, the use by the U.S. Air Force of air-delivered, precision-guided, antiarmor submunitions in a future regional conflict might conceivably stop the advance of a sizable (e.g., division-size or greater) enemy armored force in its tracks, without requiring intervention by U.S. Army mechanized forces.⁴⁰ If this were to occur, and if it could be confidently accomplished in a wide variety of tank-accessible terrain and in the face of enemy air defenses, it would be a true RMA, since it would render irrelevant a core competency (tank/antitank warfare) of a dominant player (the armored forces of the U.S. Army).

⁴⁰See Bowie et al. (1993).

As another example, the employment of cyberspace-based techniques by one side in a future conflict might inflict strategic damage on the other side sufficient to significantly alter the course of the conflict.⁴¹ If this were to occur, it would also be a true RMA, since it would create a new core competency (information warfare) in a new dimension of warfare (cyberspace).

Neither of these—nor other examples that have been mentioned in the recent military-technical revolution/RMA literature—has as yet occurred. But because they could, the jury is still out regarding whether the current military-technical revolution will result in one or more true RMAs.

This conclusion is in keeping with Andrew Marshall's initial words regarding what has come to be called "the RMA":

There is also a tendency to talk about **the** military revolution. This could have the sense that it is already here, already completed. I do not feel that is the case. Probably we are just at the beginning, in which case the full nature of the changes in the character of warfare have not yet fully emerged; therefore, the referent of the phase, "the military revolution," is unclear and indeed should remain to some extent undefined. It would be better to speak about the **emerging** military revolution, or the **potential** military revolution. What we should be talking about is a hypothesis about major change taking place in the period ahead, the next couple of decades. (Emphasis in the original.) (Marshall, 1993.)

Indeed, by prematurely declaring the current military-technical revolution a "revolution in military affairs," the most enthusiastic proponents of "the RMA" may have unnecessarily opened themselves up to criticism.⁴²

⁴¹See Molander et al. (1996).

⁴²Mann (1998) is but one example of such criticism. Even worse, by terming the ongoing military-technical revolution "the" revolution in military affairs rather than merely "a" revolution in military affairs, as if it were the only RMA that ever occurred, the proponents of "the RMA" show a lack of historical sense.