

An Introduction to the Revolution in Military Affairs

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XV Amaldi Conference on
Problems in Global Security

Helsinki, Finland
September 2003

Introduction

The concept of a "revolution in military affairs" has become such a pervasive topic of discussion among security experts that it has now acquired the shorthand of its initials—RMA—as the representation of a wide range of loosely connected ideas and approaches in security policy. There is controversy over whether there has been, is now, or will be a revolution in military affairs, or what constitutes a change in security that might deserve such a name. There is little doubt that upheavals such as gunpowder, air power, and nuclear weapons have marked true revolutions in military affairs, but there is no consensus on whether the recent changes in military weaponry and strategy made possible by advances in information technology should be called a revolution.

The genesis of the current thinking about a revolution in military affairs began in Russia in the early 1980s, when Soviet Marshal Nikolai Ogarkov, the Soviet chief of staff at that time, wrote about a "military technical revolution" that would dramatically improve the lethality and capabilities of conventional weapons (Cohen). Ogarkov and his colleagues were familiar with the technical progress in American weaponry that appeared during the war in Southeast Asia. In 1970, two years before the invention of the microprocessor, U.S. Army General William Westmoreland testified before Congress and said:

On the battlefield of the future, enemy forces will be located, tracked and targeted almost instantaneously through the use of data links, computer assisted intelligence evaluation, and automated fire control. . . .I am confident the American people expect this country to take full advantage of its technology—to welcome and applaud the developments that will replace wherever possible the man with the machine (Congressional Record 1970).

The Soviet military was profoundly threatened by such American designs, because the chief advantage of the Warsaw Pact forces in Europe in the 1970s and 1980s was sheer numbers of military assets, and the Soviet military leaders were well aware of their country's inability to compete with the West in computer technology. Marshal Ogarkov's musings about a military technology revolution were meant as a wake-up call to his own country's political leaders, it now appears.

The ideas discussed in the Soviet military literature eventually migrated to the United States Department of Defense and to a rather obscure Pentagon agency, the Office of Net Assessment, which has been run for decades by Andrew W. Marshall. Marshall has developed a small but influential thinktank within the Pentagon since 1973 and he is known for his skepticism and criticism of traditional service-bound military priorities, such as large ships, elaborate aircraft and heavy tanks. Marshall became the leading proponent of a revolution in military affairs and has nurtured a long list of intellectual disciples who have distributed themselves throughout the intellectual community of security policy experts in the U.S. To his disciples and insiders at the Pentagon, the 82 year-old Marshall is known as "Yoda," the name of the wise but diminutive "Jedi master" in the "Star Wars" movie series (McGray).

Marshall has enjoyed a particularly close relationship to the current Secretary of Defense, Donald Rumsfeld, who held the same office during the Ford administration and who,

between these two periods, served on numerous Pentagon study panels. In fact, Rumsfeld, Vice President Dick Cheney (also a former Secretary of Defense) and Deputy Secretary of Defense Paul Wolfowitz are all Marshall protégés, in the opinion of some Pentagon watchers (McGray). James G. Roche, Rumsfeld's selection in 2003 for Secretary of the Army, was Marshall's chief military aide from 1975 to 1979 (Kaplan). Thus, in the Bush administration Marshall's influence has rather dramatically risen, and the revolution in military affairs—now marketed as "defense transformation" to the Congress and the news media—is at the core of the administration's defense policy.

Both Iraq wars, in 1991 and 2003, can be considered stages or phases of the RMA. Each conflict displayed particular features of the RMA and U.S. weapons development and each served as a demonstration, a "demo," to other nations, of the "state of the art" of military weaponry, command and control and strategy. Because of the transformation of the U.S. military by the thinking behind the RMA and the new technologies associated with it, other countries throughout the world are confronted with the question of whether to pursue similar approaches in their defense policies, in order to remain credible as military powers, or whether to abandon military competition and search for alternatives. China, for example, has recently announced its intention to modernize its military by abandoning its long-held commitment to an immense standing army, because Chinese military leaders have apparently concluded that the RMA is real and that to remain a military power, China must become a modern force. Small European countries, on the other hand, are assessing specialized niche roles in military alliances instead of trying to field a full range of military forces. In short, the features of the RMA—whether defense transformation deserves to be labeled a "revolution" or not—are having a profound impact on the character and size of military forces throughout the world.

Elements of the RMA

The RMA is a somewhat nebulous and mutable concept that has had many different interpretations, even among its most ardent proponents. But there are some relatively stable elements that are identified with both the phrase and its policy implications.

Great advances in computational power, decreases in the physical size of computer components, and lower costs lead to dramatic progress in military technologies—Several military historians have pointed out the fairly obvious observation that progress in military technologies is usually tied to progress in the technological and economic base of countries fielding a military. Large standing armies depended on agricultural surpluses, and Napoleon's huge army depended on the kinds of logistical complexities that had allowed cities to feed off of remote farms. The American Civil War, World War I and World War II were obviously wars of heavy industry. So the information technology revolution, as Westmoreland presciently predicted in 1970, eleven years before the personal computer revolution took off, would be expected to have a transformative impact on military technology, and so it has. One example frequently mentioned in the literature as a landmark was when U.S. bombers flew 800 bombing sorties over the Thanh Hoa bridge in North Vietnam, losing ten aircraft without damaging the bridge, but then the bridge was destroyed in one pass by four Phantom F-4 fighter-bombers using laser-guided Paveway 1 bombs (U.S. News and World Report 1987). The "precision-guided munition," or PGM, debuted in Vietnam.

Computer experts and military technologists are typically enthralled by Moore's Law, a 1965 prediction by Intel Corporation co-founder Gordon Moore, who said then that the density of transistors on a computer chip would double every eighteen months. Moore's Law has been remarkably accurate even until today, although the fact that Moore's company, Intel, has led the semiconductor industry throughout this period has undoubtedly had something to do with the fulfillment of Moore's prediction. Moore's Law has become almost as revered as Newtonian law, and it has presided over a spectacular and epochal transformation of nearly every corner of industrialized societies, including military technology. Everyone is by now familiar with the dimensions of the information technology revolution, whose main elements have been the personal computer, lightning-fast global telecommunications and the Internet.

The U.S. military sponsored the earliest research into electronic digital computers and the Pentagon was the largest customer of computer companies until about the 1970s. As computers got smaller and cheaper they proliferated in businesses and then eventually became consumer goods. This explosion in the market for computer technology shifted the focus of innovation from military technology to business and consumer technology, to the point that in most cases, gadgets on the market for consumers are more sophisticated than many military assets. This has created a new environment for military planners and researchers—now, it is not uncommon for military technologies to absorb advanced technologies from the commercial sector instead of the other way around, a switch from the old model of "spin off" to the new one that some people call "spin in." This has had the effect of expanding the range of technologies relevant to military affairs, as well as allowing the military to take advantage of privately-funded research and development and the lower prices that come from larger markets.

Many of these factors combine synergistically in the military context; as prices fall for information technology components that are increasingly capable, weapons like munitions that use these components can become both more deadly and more numerous. Likewise, as communications networks become both more ubiquitous and more sophisticated, spanning both terrestrial and space elements, military command and control can do more and in more places. Even military intelligence has become dependent on sources of information that are otherwise "civilian," such as the news media and the Internet.

Expanding military capabilities have more or less mapped to the expanding capabilities of businesses and people in civilian life: enhanced discrimination, information, dissemination, and analysis. In the military context these have all been combined with firepower in order to transform the lethality, speed and effectiveness of military force.

Joint service commands and "data fusion"—The traditional form of national militaries has been to divide them into service branches such as the army, navy, air force and marines. In the past each branch has pursued its own internal goals and developed its own traditions, doctrines and strategies, cooperating with other branches as needed. Inter-service rivalries, redundancies and conflicts have been common.

In the digital information age, artificial obstacles to sharing information must be overcome so that computer-based information systems can "talk" to each other. Moreover, the appearance of highly accurate "stand-off" weapons that can be deployed from a variety of military platforms—such as ships, aircraft or land-based vehicles—make inter-service cooperation

vital. Finally, the information processing and data collection capabilities of new technologies makes possible a level of coordination among service assets inconceivable in earlier eras of combat.

Because of these kinds of new capabilities and requirements, an important feature of the RMA are joint-service commands and "data fusion" from all service elements so that a single command can get important information from all parts of the battlespace. Joint-service commands have evolved in the U.S. military since the war in Southeast Asia and in the last war in Iraq the joint-service command of the coalition was perhaps the most successful and effective ever demonstrated. The wide distribution of common information and data processing capabilities, new command and control systems, and supportive elements such as space surveillance, command and control aircraft (JSTARS and AWACS), and unmanned drones have all contributed to data fusion. A goal of joint-service commands and data fusion is to deliver the right weapon at the right time and the right place no matter which service is called upon to deliver it. This is an extremely complex task, and one of the tragic byproducts of this approach, which is "friendly fire" or attacks on one's own forces, is still a major problem for the U.S. military and its allies.

Eliminating the "fog of war"—The phrase "fog of war" is attributed to the famous 19th century military thinker Carl von Clausewitz, who, in his book *Vom Krieg* (On War), laid out many of the foundations of modern military strategy. Clausewitz never actually used this phrase, but it has stuck to his name anyway, enough that people who believe that elimination of the unpredictability and chaos of war is impossible are today often called "Clausewitzians," a point I will return to later (Kiesling).

The argument of some proponents of the RMA is that new technologies will help "lift the fog of war"—this is a title of a book by retired U.S. Admiral William A. Owens—and allow a military power like the United States to command a battlefield like a chess game in which all the enemy's pieces are visible and vulnerable, and all the friendly pieces are visible and commandable. Owens is an advocate of the "system of systems" approach, a term more fully explained later, in which an all-encompassing and all-knowing technological system manned by commanders can both deploy subsystems of force and "see" all the assets and vulnerabilities of the enemy. Such a transparent battlefield has been a goal of military planners since human conflict first appeared, but its importance has risen in tandem with the increasing complexity and speed of modern combat. These days, part of the RMA is the goal of "battlespace dominance," which means not only superior force but superior information. Enormous sums of money are spent on technologies and training to accomplish this goal (Owens).

Agile, lower-cost weapons platforms deploying "zero-CEP" precision munitions— One of the more controversial elements of the RMA argument is that expensive weapons platforms like ships, manned aircraft and big land-based vehicles should be phased out in favor of smaller, less expensive, and possibly unmanned vehicles such as flying drones and simpler stand-off weapons platforms that can deliver accurate precision-guided munitions from a distance. The most expensive and vulnerable item in the military arsenal, for example, aircraft carriers, may eventually be replaced by cheaper ships that simply launch "swarms" of targetting drones and powerful and accurate cruise missiles. Big artillery pieces are likely to fade into history,

according to some RMA advocates, replaced by systems like Predator drones armed with Hellfire missiles, or surveillance drones that report to a distant battery of cruise missiles.

PGMs, the technological key to such reforms, are increasingly accurate, approaching the "zero circular error probable" goal—meaning accurate enough to match the target with the lethality of the warhead—their cost is dropping, and their accuracy means that fewer of them are needed to destroy enemy targets. In the 1991 Gulf War in Iraq, for example, about 20 percent of bomb munitions were "smart" weapons, out of a total of about 265,000 bombs dropped. In Iraq in 2003, however, nearly all the bombs used were precision-guided, and only 27,000 were used, or a little more than ten percent of the figure of 12 years earlier (Childs). The new technology used in the U.S. military called JDAM, for Joint Direct Attack Munition, is an add-on to conventional, "dumb" munitions which makes them "smart" by including inertial guidance and communication with the satellite-based Global Positioning System or GPS. This is an inexpensive modification to munitions already in the U.S. arsenal, and 6,542 of them were used in Iraq in 2003, out of 18,467 precision-guided bombs (Dunnigan).

The lethality and accuracy of PGMs means that not only does it matter less who fires them, or where they're fired from, but there are fewer platforms required. Evidence suggests that during the air war in Kosovo, for example, U.S. forces ran out of key targets rather quickly in the conflict because of the accuracy of PGMs either dropped or fired on Yugoslavia. The U.S. lost only a single aircraft in that conflict—its crew was recovered—and suffered no casualties from enemy fire. The implications of defeating an entire country with this level of military imbalance, because of stand-off PGMs, were felt around the world.

Fast, deadly, smaller-unit force structures—The combined capabilities of battlespace dominance, elimination of the fog of war, and PGMs suggests to some advocates of the RMA concept that large military forces, with their demanding logistical requirements and sluggish movement, can be replaced by smaller, faster-moving, more agile and lethal force units. The most vocal RMA proponents argue that with good information and lethal PGMs, small units can be as deadly or even more so than the large military armies of the past, or those that still exist in some parts of the world. Consequently, RMA evangelists have pressed for reforms in military command structures and reallocations of weapons and training in order to build a smaller but more effective military force.

One implication of this approach is the idea that the individual soldier becomes less a fighter than a sensor. The "soldier as sensor" is not entirely new; it has been the mission of an artillery unit's "forward observer," a soldier typically assigned to an infantry unit in order to order artillery fire when and where it's needed. RMA philosophy makes every combat soldier a forward observer, at least in theory, with an ability to call on a wide range of distant forces that can deliver munitions where the soldier needs them. The U.S. Army sometimes talks about "pop-up" forces, which means small, stealthy units that can "pop up" to identify an enemy target, then tuck into safety to call in lethal and accurate PGMs. Once that target is destroyed, the unit moves on to other targets. Such units actually try to avoid head-on, small arms firefights with an enemy, in contrast to conventional battles in the past.

The United States' recent engagements in Afghanistan and Iraq have also boosted the significance and use of Special Operations forces, which are by design organized into small and highly trained units. Special Operations forces are usually assigned close combat

missions in short bursts of intense activity, often involving some kind of dangerous infiltration that would be difficult or impossible for larger combat units. Now with the availability of PGMs, Special Operations forces can deliver overwhelming force to targets deep within enemy territory, usually by using laser target identification systems and secure communications. In Afghanistan, U.S. Army Special Forces units acquired the support of indigenous Afghan forces because of the Special Forces soldiers' combination of personal bravery on the ground and their ability to summon spectacular and devastating firepower from the air.

The Pentagon's attempt to limit forces used in Iraq in 2003 to a minimum necessary to defeat the Iraqi Army became a controversial aspect of that war. Some U.S. commanders were angry that there were insufficient forces in Iraq to provide logistical security, for example, or to prevent looting. The speed of the American advance from Kuwait to Baghdad was also controversial, because it left some units exposed to enemy fire and may have contributed to some "friendly fire" casualties. The U.S. military is still figuring out the right size of forces in the context of defense transformation (Rieff).

RMA Paradigms

Michael O'Hanlon of the Brookings Institution in the United States has identified four RMA "schools of thought," or paradigms, in his 2000 book *Technological Change and the Future of Warfare*.

The four schools of thought within the RMA philosophy in the U.S., according to O'Hanlon, are the "system of systems," the "dominant battlespace dominance" school, the "global reach, global power" paradigm, and the "vulnerability" school of thought, which stresses the contention that new technologies will not be monopolized by advanced military powers but will eventually "leak" to adversaries of the West.

The "system of systems" approach is by now widely accepted in the U.S. military. The phrase describes a comprehensive hierarchy of command structures and technologies, across all services and including civilian command authorities, as well as an integration of force delivery systems on all platforms and among all military units. In other words, the "system of systems" school of thought is the skeleton and muscles of "jointness," or the integration of all military forces and command, a goal to which the U.S. military has been working for over two decades. The organizational reforms leading to this goal have been accompanied by dramatic progress in the technologies of command, computers, control, communication and intelligence processing, or what the military calls C⁴I. In both wars in Iraq, the U.S. military practiced a virtual "real-time" war of command and control through all levels of command, from the small unit at the forward edge of the battle to the Pentagon and the White House in the United States. Increasingly, commanders rely on "data fusion" from a wide range of information inputs including soldiers, aircraft, drones, sensors, satellites, and increasingly sophisticated radars and photoreconnaissance technologies. This onslaught of data is collected, processed and to some extent analyzed by automated systems, in conjunction with military experts. Once enemy movement or an enemy presence is detected and confirmed, force delivery can be mobilized very quickly and the enemy's interdiction can be monitored throughout a military's command structure.

The "dominant battlespace knowledge" school of thought, O'Hanlon says, "is much more bullish and ambitious than the system of systems school" (O'Hanlon 13). The development of a complete global surveillance system using combinations of space-based reconnaissance, aircraft, ground sensors and unmanned drones will allow future military commanders complete knowledge of "anything of consequence that moves upon or is located on the face of the Earth," according to former U.S. Air Force Chief of Staff Ronald R. Fogleman in his 1997 testimony to Congress (O'Hanlon 13, Fogleman). This contention that future battles will be made transparent by technology is controversial, however. Critics of this school of thought argue that battles will remain confusing and sometimes chaotic, and enemy forces will undoubtedly develop either technological countermeasures or other techniques to avoid being detected. Radar and communications jammers, digital encryption codes, decoys, and the simple use of human-to-human communication have all been used to defeat high-tech surveillance systems.

In Nasiriyah, Iraq, in March of 2003, U.S. Marines engaged in one of the deadliest battles of the war in Iraq. The intermingling of Iraqi forces and Marines prevented the use of precision-guided munitions against the enemy and the Marines resorted to small-arms fire in a vicious close-combat firefight. Reinforcements that were supposed to back up a Marine company pinned down in Nasiriyah never arrived. And the Marines trapped on a bridge in the city claim that six of their fellow Marines were killed by a strafing run of a U.S. AH-10 aircraft (Connell and Lopez). Incidents like this demonstrate the difficulties of battlefield transparency, even when, in this case, the U.S. had a complete monopoly on technological systems of surveillance and detection.

The "global reach, global power" school of thought identified by O'Hanlon is one more step up in ambition from the "dominant battlespace knowledge" paradigm. Assuming that the United States military can identify any target anywhere on earth in close to real-time, the logical next step would be to deploy weapons systems that can destroy that target, or any combination of targets, no matter where they are on the planet. This would require the use of space-based weapons, and the United States has several programs designed to investigate the feasibility of weapons in space that can deliver force to targets on the ground. Bob Preston and Dana Johnson, et. al., of the Rand Corporation, have thoroughly described space-based weapons, both directed energy and "mass-to-target" or kinetic energy weapons, in the Rand Corporation's 2002 report *Space Weapons Earth War* (Preston and Johnson, et. al.).

Another program of research and development within the U.S. Air Force is the transatmospheric vehicle, a space plane derived from the U.S. experience with the Space Shuttle, but, under Air Force command, capable of delivering munitions to earth targets. The Hypersonic Cruise Vehicle program at the Pentagon's Defense Advanced Research Projects Agency is aimed at a space bomber that can carry a payload of about 12,000 pounds and hit any target on earth, from a continental U.S. takeoff, in under two hours (BBC News). The aircraft would deploy a bomb maneuverable in space in a long glide to earth.

Such developments are likely to encounter resistance from other countries and permanent space-based weapons like directed energy or kinetic energy weapons on satellites are currently banned by the Space Treaty. However, a steady stream of official reports on the Pentagon's commitment to control space and its assumption that space will be a future

battleground suggest that space weapons will become part of the U.S. arsenal unless there is some unexpected interruption of this trend.

As O'Hanlon also notes, the "global reach, global power" school of thought is not limited to the Air Force or to space-deployed weaponry. Both the Marines and the Army in the United States are taking steps to increase their rapid-response capabilities and to decrease their heavy-lift requirements by lightening vehicles, reducing the size of forces, and deploying forward logistical support bases around the world. For combat operations, the goal of the Army and Marines is not only to get to a theater of combat rapidly, but to very quickly and decisively overwhelm the enemy and prevent a sustained war. Success would free up these forces for use elsewhere. However, in both the Afghanistan and Iraq conflicts of recent years, troop requirements for postwar security have proven far more demanding than anticipated, and the Army feels stretched thin and at increased risk. Secretary Rumsfeld has warned antagonists like North Korea that the U.S. military is capable of securing Iraq and defending South Korea against a North Korean attack, but there is widespread doubt about the credibility of this threat unless the U.S. were to resort to nuclear weapons. In short, advocates of defeating an enemy anywhere and anytime using high-tech weapons are very far from that goal.

O'Hanlon's last school of thought about the RMA, the "vulnerability" paradigm, stresses the potential vulnerability of U.S. and allied assets like ships, planes, tanks and, after September 11th, even civilian targets, to weapons developed to support the RMA concept. The most pressing and illustrative example is the availability of Stinger ground-to-air missiles, which were introduced into Afghanistan by the United States in order to assist the mujhadeen fighters in their war against the Soviet Union's military in the 1970s and 1980s. Stingers are shoulder-fired and easy to conceal. They have a high rate of success against airborne targets because their missiles are precision-guided. There are reportedly thousands of Stingers in circulation via clandestine arms deals throughout the world—this weapon is readily available to terrorists, in other words. Terrorists have already used an older but similar shoulder-fired missile system, a Soviet SA-7, against an Israeli commercial airliner departing Kenya in 2002. The threat of precision-guided, shoulder-fired missiles against commercial airliner flights is serious enough that officials throughout the world are contemplating missile defense systems on commercial aircraft (Squitieri).

The proponents of the "vulnerability" school of thought point to a particular problem with the RMA thesis: as information technology costs drop and weapons based on such technologies get cheaper, they fall within the reach of a greater number of agents, governments, terrorist groups or other potentially threatening forces. And as the lethality of these weapons increases, the vulnerability of large expensive assets that can only be deployed by wealthy countries increases as well. Thus, while we can assume that because of the Western predominance in military spending and information technologies, we should also expect that the "lower end" of RMA weaponry will leak to adversaries, and these weapons will threaten the higher value assets of the larger powers.

Another argument of the "vulnerability" school of thought is that the acceptance of a greater and greater degree of complexity and dependence on technological systems will make modern militaries peculiarly vulnerable to systemic attacks against assets that can be unreliable or untrustworthy, like computer or communication networks. In other words, by

dramatically increasing the importance of the "system of systems" network infrastructure—its central nervous system, so to speak—the RMA philosophy increases the risk of the whole military force. If communication lines are disrupted or if military computers are successfully attacked, the highly complex mix of forces in a joint command could be at risk or even thrown into chaos.

The Warsaw Pact command planned for just such a strategy during the Cold War, and U.S. doctrine responded by incorporating the German concept of *Auftragstaktik*, sometimes known in English as "mission-oriented command." *Auftragstaktik* was used by the German Wehrmacht as a principle of combat leadership in circumstances where orders from higher command authorities were either unavailable or inappropriate to the situation at hand. *Auftragstaktik* counsels initiative and innovation by front-line commanders, who might even disobey their formal orders in order to accomplish a specific military mission. Military leaders trained under the principle of *Auftragstaktik* can function effectively even if cut off from central command authorities.

During the Cold War there was a great deal of discussion in American Army circles about the role of *Auftragstaktik* in the Western European theater, as a hedge against a Warsaw Pact decapitation strike using tactical nuclear weapons. However, the U.S. Army's adoption of *Auftragstaktik* generated some friction with other trends, such as those that pointed toward joint commands, data fusion, battle management systems and eventually the "system of systems" concept, which all tend to assume degrees of transparency and centralization that make *Auftragstaktik* unnecessary and even dysfunctional (Chapman, Dunivan). This balancing act between the mission-oriented command of autonomous units versus the control of centralized command has been one of the most difficult issues facing the U.S. military, and at any given time it seems that no participant is completely satisfied.

The "vulnerability" school of thought—which is not clearly an argument against the RMA as much as a warning about overconfidence and distorted priorities—serves as a counterbalance to some of the more hubristic proponents of the RMA. Defense transformation is never a one-sided activity, as September 11th so dramatically demonstrated. Even if we assume that future wars will be "asymmetric," in the jargon of the day, meaning that there will be a severe imbalance in force capabilities and sophistication, asymmetric opponents will not be utterly primitive; they will have access to at least some high technology weaponry that is likely to be the by-product of the RMA philosophy. When you combine this likelihood with the discouraging probability that opponents will fight in ways designed to create fear and terror within civilian populations, the character of some marvel weapons takes on an added dimension that RMA proponents are not apt to acknowledge.

Components of the RMA "System of Systems"

The following table (table 1) describes the basic components of a comprehensive, modern array of components representing the RMA concept.

Intelligence, Surveillance and Reconnaissance (ITR)	Command, Computers, Control, Communications, Intelligence Processing (C4I)	Precision Force (PGMs)
Stealth technologies	Lightweight, lower-cost, agile weapons platforms	Information warfare
Space weapons	Missile defense	"Operations Other than War"

Table 1: Components of the RMA "System of Systems"

Intelligence, Surveillance and Reconnaissance (ITR)— The elements of ITR include sophisticated radar monitoring, satellite surveillance and reconnaissance, unmanned aircraft like the Predator with advanced radars and video cameras, airborne and land-based sensors, and the expensive aircraft jointly deployed by the Army and Air Force called the Joint Surveillance and Target Attack Radar System or JSTARS. The JSTARS aircraft is an airborne command center for ground combat, a complement to the Air Force's AWACS aircraft for command and control of air operations.

Computers, Control, Communications, Intelligence Processing (C4I)—C4I elements include both forward and rear command and control technologies, secure communications and computer processing that ranges from laptops and handheld computers in the field to immense supercomputers in the continental United States, and everything in between. An increasingly important element of C4I is the Global Positioning Satellite system, or GPS, which helps pinpoint the location of everything under observation, both enemy and friendly forces and assets. The U.S. has also invested heavily in computerized "battle management systems" designed to aggregate data about a combat operation and present it to commanders in a form that is helpful to planning and execution.

Precision force (PGMs)—PGMs include the by-now familiar Tomahawk cruise missiles launched from ships and aircraft; "smart" bombs such as the GBU-12 laser-guided bomb or bombs guided by GPS; a wide range of guided missiles such as the Hellfire laser-guided, air-to-ground antitank missile; older munitions retrofitted with the JDAM package described above; and ground-fired, man-portable missile systems such as the Javelin, a 28-kilogram weapons package that fires a "fire and forget" antitank missile guided by a heat-seeking warhead that locks onto an infrared signature acquired by the operator. There are more than 80 missile types in the U.S. military's inventory, and in general they are all moving to "smart" capabilities using one or more technologies such as laser-guidance, GPS, anti-radiation, heat-seeking, and terrain-mapping, among others. A new capability demonstrated in Afghanistan and Iraq is the use of unmanned aerial vehicles (UAVs) such as a Predator, armed with Hellfire missiles that can be targeted using radar or video cameras onboard the drone. In

addition to the actual guided munitions, PGMs are sometimes guided to their targets by human observers using laser target acquisition systems, in which a laser beam aimed at the target by soldiers creates a "target signature" that can be used to guide a munition to the target.

While PGMs have displayed tragic and controversial errors, missing targets and hitting civilians or buildings that should not have been targets, the use of PGMs in recent conflicts such as Yugoslavia, Afghanistan and Iraq has showed how remarkably accurate—and devastating—they have become. A phenomenon reported by most journalists in Baghdad during the March 2003 bombing of the city was that Baghdad residents became so confident of the accuracy of coalition strikes that they would watch the nightly bombings from rooftops and windows. Many journalists also remarked how most of Baghdad escaped any serious damage from bombs even while targeted buildings in the city were utterly destroyed. The significance of the changes that highly accurate PGMs have brought to warfare can hardly be overstated.

Stealth technologies—The United States Air Force is the only military force in the world deploying so-called stealth aircraft, both the B-2 Bomber and the F117-A Nighthawk Stealth Fighter, which both have dramatically reduced radar signatures. The F117 has a radar cross-section of between 10 and 100 square centimeters—at the most, the area of a 4-inch square—for an aircraft 66 feet long and 43 feet wide (airforce-technology.com). These two aircraft are currently used for night operations only, although the Air Force is investigating the use of the F117 for daylight operations. Stealth technologies for low-observable aircraft are expected to be included in most future combat aircraft, in particular the Lockheed Martin X-35, which was selected by the Pentagon in 2001 as the next F-35 Joint Strike Fighter platform. However, some military experts have noted that stealth aircraft are less important than once thought because of the effectiveness of antiradar PGMs against air defenses. PGMs are vastly cheaper than stealth aircraft, and their suppression of air defenses in Yugoslavia and Iraq seemed to raise questions about the need for expensive stealth aircraft.

Lightweight, lower-cost, agile weapons platforms— The ability of smaller platforms to deploy increasingly lethal PGMs and ITR technologies is combining with technological advances in armor and logistics to lower the weight, size and cost of many weapons platforms. The U.S. Army's new Stryker Interim Armored Vehicle, for example, can be transported in the Air Force's ubiquitous C-130 air cargo planes, instead of requiring the larger and heavier C-141. The use of the lightweight and unmanned Predator UAV as a surveillance and weapons platform has already been mentioned. The Predator can fly for up to 20 hours, much longer than larger, manned aircraft with similar missions. The U.S. Navy is reevaluating its commitment to a large number of ships because of its experience in using standoff PGMs such as the Tomahawk. Most militaries in the Western alliances are aiming new platform development at cheaper, multi-use vehicles that can be configured with specific equipment for different missions, a contrast to the proliferation of specialized vehicles that characterized the Cold War era.

Information warfare—A topic that has spawned its own voluminous literature, the phrase "information warfare" can cover many different activities, including computer attacks, computer defense, misinformation campaigns, propaganda, psychological operations and both attacks on and defense of communications networks. The proliferation of inexpensive

computers and mobile telephones has given information warfare new significance and new targets, and of course an RMA-type military is increasingly dependent on information technologies and systems, which become new points of vulnerability. The 1991 Gulf War was said to be the "first war of information," in that the coalition's information dominance led to several instances of coalition forces interdicting the Iraqi Army before it could acquire a strategic hold on territory. Obviously the use of PGMs on enemy forces requires critical and reliable information about the enemy's location, and poor information can become a serious liability, such as when the U.S. mistakenly bombed the Chinese embassy in Belgrade, creating an international incident that had multiple repercussions. Finally, several of the most recent conflicts between asymmetric forces have been less a matter of annihilating the enemy than of "managing expectations," or sapping the enemy's will to continue fighting. This was certainly the case in the Kosovo conflict with Yugoslavia. In such contexts, information warfare takes on the central function of changing the enemy's mind, rather than serving as a tactical adjunct to more conventional military operations.

Space weapons and missile defense—Some trends in space weapons have been discussed above, such as the transatmospheric vehicle and possible orbiting weapons designed to engage targets on earth. Other space weapons include anti-satellite weapons or weapons designed to defend space assets such as the GPS system or communications satellites. The "weaponization" of space is presently prohibited by international treaties, but this has not halted many different U.S. weapons plans; indeed, the U.S. has an entire Space Command within the Air Force, which is specifically charged with planning for space as a field of military conflict. The current U.S. Chairman of the Joint Chiefs of Staff, Air Force General Richard B. Myers, is the former head of U.S. Space Command.

Missile defense includes both ballistic missile defense against attacks by intercontinental ballistic missiles, and tactical missile defense against theater-based missiles. The United States' ballistic missile defense system is well-known, stretching back to President Reagan's famous launch of the Strategic Defense Initiative in 1983, a program that continues today and which has recently been accompanied by the U.S. withdrawal from the Anti-ballistic Missile Treaty. Tactical theater missile defense is also an area of intense research and development, largely to improve the U.S. Patriot missile program, which was used in both wars against Iraq. The Patriot system has been the subject of ongoing controversy, first because of disputes about its effectiveness against Iraqi Scud missiles fired into Israel in 1991, and in 2003 because of at least two "friendly fire" incidents, one of which involved a Patriot missile shooting down a British fighter aircraft, killing the two airmen (Kilian).

"Operations Other Than War"—The phrase "operations other than war" is a catch-all term for military activities not covered by the other elements of the RMA, but in recent years this category has constituted a growing share of military commitments. It includes peacekeeping, civil affairs, humanitarian aid, special operations, hostage rescue, anti-terrorist actions, policing, and a range of activities associated with the controversial mission of "nation-building." Increasingly, military planners assume that military conflicts will take place in "failed states" in which many or most of the basic human services of successful states need to be replaced. The rising threat of terrorism within formally friendly states that may have restive and hostile populations, such as in Iraq today, is an additional complication to military planning. The military may even become involved in information campaigns designed to shape public opinion in its area of operation.

Post 9-11: Network War and the RMA

The technological developments that contributed to the idea of an emerging RMA began during the Cold War and started to change the U.S. military as it contemplated the immense Warsaw Pact force in Europe. The earliest signs of the RMA were found in PGMs and new battle management technologies that were deployed as "force multipliers" in Western Europe. NATO attempted to match the numerical superiority of Warsaw Pact forces, especially its battle tanks, with sophisticated "one shot, one kill" munitions. In other words, the historical roots of RMA thinking are tied to conventional warfare between massed armies, the kind of confrontation once found in Europe and still extent in Korea, for example. The first full demonstration of these technological developments occurred in the Gulf War of 1991, which was also a war resembling the kind of classic armored battle that the U.S. military had prepared for in Europe, although the Iraqi Army was vastly overmatched by the coalition forces.

The conflict over Kosovo and the U.S. bombing of Yugoslavia began to change this picture. In Kosovo, American technological superiority had little effect on the violence in the area. The U.S. had to resort to bombing targets in Belgrade and other parts of the Serbian territory of Yugoslavia, and even then American commanders underestimated the resilience of Yugoslav forces. The Serbs were never capable of fielding an army that might challenge a conventional NATO or U.S. force, but they nevertheless deployed a mix of regular army troops, paramilitary gangs, tanks and artillery that unleashed hellish violence on Kosovo but yet stymied the overwhelming military force of the U.S. Because of this, and also because of the American experience in Mogadishu, Somalia, some experts began to question whether the RMA, with its orientation to classic conventional warfare, was appropriate to new forms of conflict.

September 11, 2001 changed everything, as we all know now. The al-Qaeda threat was not entirely new, of course—the U.S. had seen attacks by al-Qaeda-linked terrorists in Saudi Arabia, east Africa, and Yemen before September 11th. But the spectacular terrorist attacks inside the United States, with their devastating psychological consequences for the U.S. government and the American people, "revolutionized" warfare for the U.S. far more than any mix of military technologies had done to that time. Indeed, this particular revolution happened nearly overnight.

Al-Qaeda represents an entirely different sort of adversary for the United States than the U.S. has faced in the past. The battle against the terrorist organization is a good example of what some theorists have come to call a war against a "network," as opposed to war against an easily circumscribed, identifiable enemy military. John Arquilla and David Ronfeldt, of the U.S. Naval Postgraduate School and the RAND Corporation, are the two thinkers most identified with the idea of "netwar," as they call it, and they write:

The rise of networks means that power is migrating to nonstate actors, because they are able to organize into sprawling multiorganizational networks (especially "all-channel" networks, in which every node is connected to every other node) more readily than can traditional, hierarchical, state actors. This means that conflicts may increasingly be waged by "networks," perhaps more

than by "hierarchies." It also means that whoever masters the network form stand to gain the advantage (Arquilla and Ronfeldt, 3).

"Network war," and the systematic destruction of "nodes" in a network so that the network collapses, is now the predominant mode of U.S. military activity throughout the world, especially in Afghanistan, Iraq, the Philippines, Indonesia and elsewhere, and this is also the main activity of the Israeli military against Palestinian terrorist organizations.

It is not yet clear how the concept of the RMA "maps" to "netwar" or "network war." The United States military is still adapting to terrorism and combat with non-state actors. Clearly the use of RMA-like technologies in Afghanistan and Iraq were instrumental in defeating the Taliban and the Iraqi Army, but the difficulties the U.S. military has faced in the aftermath of those defeats have raised questions about the appropriateness of expensive high-tech systems in anti-terrorist or counterinsurgency conflicts. In general, however, the U.S. defense budget has simply expanded to cover both high-tech weapons systems designed for conventional combat and new systems and research aimed at countering terrorism and insurgencies.

One new development that is directly a result of September 11th is a dramatic blurring of boundaries between military, intelligence and law enforcement agencies and missions. The U.S. Patriot Act, passed within the first month after September 11, 2001, explicitly eliminates earlier restraints on cooperation between the Central Intelligence Agency and the Federal Bureau of Investigation, two agencies that have previously been isolated within their respective domains of foreign intelligence and domestic law enforcement. Today the FBI operates worldwide, assisting the military and foreign governments in fighting terrorism, and the CIA has increased its paramilitary operations, which are now often indistinguishable from the military's special operations activities. A byproduct of this new collaboration is that there is increased sharing of technologies and systems—such as intelligence analysis systems or surveillance technologies—that were once reserved for specific agencies and guarded with some proprietary zeal. This has become a new feature of this unexpected twist to the RMA, which began with a focus on high-tech PGMs and which now covers technologies developed, for example, for monitoring civilian mobile telephones or personal computers. Some people concerned about the blurring of boundaries between the military, law enforcement and intelligence agencies warn about the potential development of shadowy, clandestine forces with powerful technical capabilities, decoupled from the formal rules of conventional military commands and international law.

The RMA and Alliances

A growing controversy about the United States' heavy investment in new defense technologies is whether the U.S. is "pulling away" from other countries, including its allies, so decisively that there is little military contribution allies can make to a coalition effort. As U.S. "jointness" intensifies and becomes more complex, there is the question of whether the U.S. pays as much attention to the inclusion of allied forces and commands. As the military technology deployed by the U.S. becomes more sophisticated and in some cases spectacularly expensive, some U.S. allies are wondering whether there is any point in trying to "keep up." The very sophistication of defense technology makes the United States hesitant to share it with other nations, which creates further tensions with allies. The U.S. government has been urging Western European governments to boost their defense spending to levels matching

the proportional share of gross domestic product that the U.S. spends, to around 3-4 percent of GDP, but Europeans are averse to spending this much on defense when the United States military is so far ahead of all others that any role for allies appears to be largely one of political endorsement rather than a militarily significant contribution. Some countries are beginning to concentrate on peacekeeping as a specialty, for example, rather than attempt to field a combat force that can match the capabilities of the U.S. military.

This picture does not apply to all countries, of course. Britain and the United States still enjoy their "special relationship," and Britain's participation in the Iraq war only helped to cement this. The positions of Germany and France will certainly have repercussions with respect to collaboration with the United States. A problem for European companies in the defense business is that they have been concentrated among the heirs of heavy industrial land armament manufacturers, with fewer defense contractors in the information technology or space-oriented fields. With static or shrinking defense budgets in Europe and fewer firms providing "synergy" between high technology and armaments, continental Europe is poised to fall further behind the United States in military technologies and deployed systems. This is likely to be true even if the European Union is successful in creating a European military force separate from NATO, a plan pushed by Germany, France, Belgium and Luxemburg. The European direct action force, whose future is uncertain, has created additional friction with Washington, which is concerned about the development of an independent European foreign policy.

The decision of the Bush administration to freeze opponents of the war in Iraq from bidding on contracts in the reconstruction of that country will likely add to the tensions developing in the Western alliance. The Bush administration and its conservative supporters in the U.S. frequently use the phrase "new Europe" to describe the states they regard as friendly to U.S. foreign and military policy, primarily the states of the former Soviet bloc in Eastern Europe, and this suggests a new tendency toward favoritism on the part of U.S. policymakers, a context in which some European states are included in RMA-like military reforms and some are not. Connections between profitable high-technology defense contracts and this new favoritism remain to be seen, but the message is not lost on the participants.

The Western alliance is not threatened by the RMA—there are many more profound differences within the alliance than the disparities in military technology that now exist between the U.S. and everyone else, with the possible exception of Britain. France and Germany's opposition to the war in Iraq in 2003 will certainly have the greatest impact on U.S.-European relations.

However, the RMA is a contributory factor in the potential decoupling of the United States military and its allies, and it contributes non-diplomatic reasons, even purely technical reasons, for such a decoupling. The greater the disparity between the U.S. military's capabilities and that of all other nations, the greater distortion there will be in foreign policy, as the U.S. is capable of "going it alone" and other nations are capable merely of token endorsement or niche roles such as peacekeeping or policing. U.S. hegemony is based in part on the country's immense defense budget and the spectacularly effective weaponry such spending has purchased. But it is not yet clear whether U.S. hegemony also means unipolarity in the world system, or whether there will be independent sources of legitimate policymaking even when those sources cannot match U.S. military power.

Critiques of the RMA

The idea of a revolution in military affairs has its critics. There are those who challenge the appropriateness of the word "revolution" to describe what's happened in military technology. There are others who think that the claims of the RMA advocates are extravagant and perhaps dangerous because the claims might lead to overconfidence, or, worse, to easy "push-button war." There are some critics who accept the fact that there is an ongoing revolution in military affairs but who think that the source of this revolution is not technology but the confrontation with non-state actors such as global terrorist networks. And there are critics who argue that the RMA is simply fuel for extension of the arms race beyond the years of the Cold War, and that cheaper but more lethal weapons will come back to haunt us.

It sometimes surprises non-experts, but one of the chief sources of criticism of the RMA concept has been the officer corps of the U.S. military. There is significant friction between the officer corps, especially line combat commanders in the Army, and the advocates of high technology systems in the civilian leadership of the Department of Defense. This friction has grown since the plans for attacking Iraq began to acquire Bush administration support, and conflict between Secretary of State Donald Rumsfeld and the senior leadership of the U.S. Army is now well-known. As one Army officer told *The Washington Post*, about Rumsfeld, "Does he really hate the Army? I don't know" (Loeb and Ricks).

One retired four-star Army general told me, "What is the RMA? Is it a roadmap? A philosophy? An ideology?" The Pentagon's current phrase for the RMA, "defense transformation," has become, under Rumsfeld's leadership, a kind litmus test for senior officers. "Rumsfeld decides whether you're 'transformative' or not, and if you're not, you're not on his team," said the retired general. Senior Army generals felt they had their own vision of transformation, but that this was undercut by Rumsfeld's abrasive style and his dismissal of several top Army leaders, who he replaced with his own hand-picked supporters. Civilian aides to Rumsfeld also recommended cutting several of the programs the Army had developed in its own transformation plan (Loeb and Ricks).

Many of the disputes between the civilian leadership of the Pentagon and the career military officers in the Army came to a head over the invasion of Iraq. Many senior commanders were angered and dismayed by civilians in the Bush administration who claimed that the invasion of Iraq would be easy—a prominent member of the Defense Policy Board, Kenneth Adelman, pronounced that Iraq would be a "cakewalk" (Adelman). Before the war, Army Chief of Staff General Eric Shinseki testified before Congress that he believed the Army would need up to 200,000 troops to secure Iraq, a number that was immediately condemned as far too large by civilian Pentagon leaders. (At the end of 2003 there were 130,000 U.S. Army troops in Iraq.) During the war, both retired military officers commenting on the war on television (including subsequent presidential candidate Wesley Clark) and, on one rare occasion a general in Iraq itself, observed that the troop commitment in the war was too small and was compromising security. Some critics attributed the troop level to the civilian leadership's desire to demonstrate the principles of defense transformation in a real combat situation in Iraq, and were thus angered that a theory had overruled experience and possibly risked lives.

These criticisms reinforced earlier objections to the RMA concept, such as that it emphasized

technology too much and at the expense of valued military experience built up over centuries. Some military officers have complained that the RMA paints a picture of war by machines instead of war by men, which is not only offensive to the men and women who sacrifice in war but dangerous in its implications. In response to the claim that technology will "lift the fog of war," for example, Jacob W. Kipp and Lieutenant Colonel (ret.) Lester W. Grau wrote in the journal *Military Review*:

The siren song of technology is that it will eliminate the fog and friction of war. The reality is that the military's application of technology has usually created its own fog and friction. Advances in technology expand the battlefield, transform the relationship between time and space and create new demands on command and control. With the pace of scientific and technological innovation constantly accelerating, military institutions face a perpetual challenge of change, and the very nature of that challenge becomes more problematic as weapon systems become more complex. . . .

Technology will be used across the spectrum of combat but will seldom prove equally effective across that spectrum. A determined foe can work around technology to disrupt or destroy it by attacking its critical system nodes. Technology can be a strong element of military might, but it is only an element, and the principles of military art still apply. A professional military culture and a clear vision of future war are at the very heart of military foresight and can reduce, but not eliminate, war's fog and friction (Kipp and Grau).

Other critiques of the RMA concept have challenged the claims of some RMA advocates that technological advancements can reduce the size of the U.S. defense budget. Professor Cindy Williams of MIT has analyzed the budgetary requirements of several RMA-like programs and in 1999 concluded that the "extra annual acquisition costs incurred if just a few of those technologies lead to procurement programs could exceed \$25 billion" (Williams and Lind). Because of September 11th, of course, defense spending has climbed and is likely to remain high, and the picture is complicated by the continued existence of several big-ticket procurement items (like the next generation fighter plane) and the disappearance of, or cuts in, other programs, such as the Crusader artillery program or the Stryker vehicle. In any case, even for a Department of Defense committed to transformation, there is no foreseeable prospect for significantly lower defense budgets, although there may be cost savings in some specific programs.

Finally, the problem of a new arms race with inevitable "leakage" of high-tech weapons to adversaries has been mentioned already as a critique of the RMA. A version of this critique goes something like this: because of the overwhelming superiority of U.S. military forces today, adversaries are likely to avoid direct military confrontation and instead resort to some form of "asymmetric" warfare, including terrorism and guerrilla combat. These forms of warfare will have disastrous consequences for civilians, as they already have. If "smart" munitions and information warfare, for example, were to become widespread tools of conflict the result could be radically destabilized societies throughout the world, as public trust might decline in the use of computers, airlines, trains, etc.

Another version of this argument is that overwhelming superiority in conventional weapons pushes some "rogue" states and terrorist groups to seek weapons of mass destruction as deterrents, threats or outright weapons of choice. Some military observers have pointed out that the lesson North Korea seems to have absorbed from the U.S. attack on Iraq is that North Korea should have a nuclear deterrent at all costs or else suffer a similar fate. In the wrong hands, the combination of a small nuclear warhead and a precision-guidance mechanism would be the world's worst nightmare.

Conclusion

The question of whether there has been, is now, or will be a "revolution in military affairs" seems to be largely an issue of semantics today, especially after the launch of an all-out war on terrorism, which is likely to remain the most salient transformation of military affairs for some years to come, if not decades into the future. Nevertheless, there is no question that the centuries-old configuration of military forces of roughly equal capabilities confronting each other en masse has ended, and that technological developments described by the phrase "revolution in military affairs" have profoundly altered the balance of power and the conduct of military operations. The original "military technical revolution" described by Marshal Ogarkov and his Soviet colleagues has gone the way of the Soviet Union itself, but the modern, contemporary products of that revolution are still transforming war today. The spectacular accuracy of PGMs, which drastically reduces the number of munitions used in combat, is perhaps the most impressive change. This single technological change has repercussions throughout the array of systems deployed by a modern military, particularly in terms of information analysis, communication and the speed of modern combat.

On the other hand, as the recent conflict in Iraq has shown, technology does not and cannot substitute for soldiers coming face-to-face with an opponent. The air war against Saddam Hussein's regime was awesome and shocking, as intended, and probably led to the collapse of the Iraqi Army. But it was not decisive; there was still a need for ground troops practicing fire and maneuver and there were still some battles in Iraq that were practically the same experience for the soldiers as some battles of World War II.

It may ultimately be impossible to identify a single bracket of time in the development of weaponry and call it a revolution, because human beings tragically and foolishly devote so much of their energies, intellect and money to this endeavor that improvement in the means of killing their fellow human beings is never-ending and uninterrupted. We can only hope that someday this will cease.

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