# IMPROVING THE INFANTRY'S INVENTORY:
# *Can New Technologies Transform Military Operations in Urban Terrain?*

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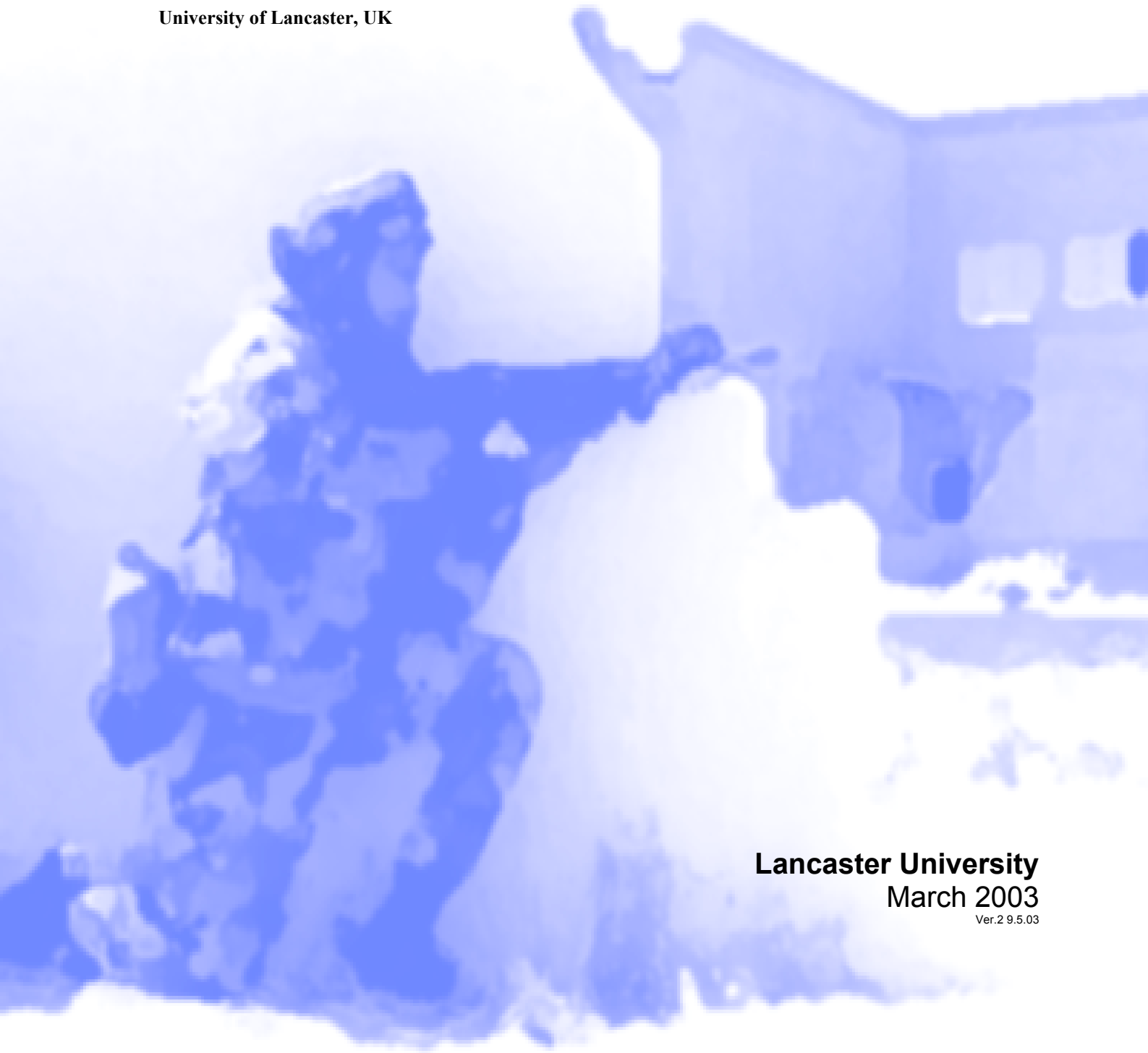

**Lancaster University**
March 2003
Ver.2 9.5.03

# IMPROVING THE INFANTRY'S INVENTORY:
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## Glossary of Abbreviations and Acronyms

| | |
|---|---|
| ADS | Active Denial System |
| BDA | battle damage assessment |
| $C^2$ | command and control |
| CENTCOM | US Central Command |
| CNN | Cable Network News |
| DAGR | Defense Advanced GPS Receiver |
| DARPA | Defense Advanced Projects Agency |
| DEW | directed energy weapon |
| DoD | Department of Defense |
| DoE | Department of Energy |
| DSR | Directed Stick Radiator |
| EW | electronic warfare |
| EMA | evolution in military affairs |
| GPS | Global Positioning System |
| HPM | high-powered microwave |
| IFF | Identify Friend or Foe |
| JNLWD | Joint Non-Lethal Weapons Directorate |
| Lidar | light detection and ranging |
| MOUT | military operations in urban terrain |
| NLW | non-lethal weapon |
| P2P | peer-to-peer |
| PEP | pulsed energy projectile |
| PSYOPS | psychological operations |
| RMA | revolution in military affairs |
| ROE | rules of engagement |
| SSW | Smart Sensor Web |
| SUOSAS | Small Unit Operations Situational Awareness System |
| TNT | tri-nitrotoluene [high explosive] |
| UAV | unmanned aerial vehicle |
| UGV | unmanned ground vehicle |
| UHF | ultra-high frequency |
| VHF | very-high frequency |

# PART ONE: Urban Operations and the Revolution in Military Affairs

# Introduction to the RMA Debate

The period since the Cold War has seen a rapid proliferation of new, potentially revolutionary technology. Few people in the post-industrial world will not be familiar with the conveniences of the information revolution – innovations that have only entered the consumer mainstream in the last fifteen years. The period has also witnessed a dramatic increase in the effectiveness of the armed forces. These new informational technologies have been enhanced and implemented into a new force structure that combines multi-spectral sensors, instant global communications, and weapons of unprecedented precision and survivability. These capabilities were initially demonstrated against the conventional forces of Iraq in 1991, and their devastating effectiveness led many strategists to believe that the US military was on the verge of a revolution in military affairs, or RMA.

## Defining the Generic

Twelve years have passed since that conflict and the debate over the RMA hypothesis continues. The concept is not altogether new but it is often used as something of a buzzword, seductively sanguine in its predictions of future military power. First used in 1955 in the context of 16th century military history[1], subsequent scholars have pointed (with debate) to examples such as the longbow, gunpowder, national mobilisation, steam engine, radar, blitzkrieg, carrier aviation, and atomic energy, as RMAs (Table 1)[2].

A revolution in military affairs is a dramatic improvement in military effectiveness that consequently alters the character of future military operations, usually instigated by technological innovation. As the military potential offered by such innovation is realised, the armed forces seek to incorporate the new capability into the military. This involves (usually in this order) the development of subsequent complementing technologies, formulation of a doctrine in which the technology and its benefits can best be used in a tactical setting, development of strategies to optimise the technology's potential, and finally the necessary re-structuring and training of the armed forces to complete the induction and operational use

[1] Michael Roberts, "The Military Revolution 1560-1660", *Essays in Swedish History* (Minneapolis, MN: University of Minnesota Press, 1967), pp. 195-225.
[2] See *inter alia* Emily O. Goldman and Richard B. Andres, "Systemic Effects of Military Innovation and Diffusion", *Security Studies*, Vol. 8 No. 4 (Summer 1999), pp. 79 – 125; also, Andrew F. Krepinevich, "Cavalry to Computer: The Pattern of Military Revolutions", *The National Interest*, No. 37 (Fall 1994).

of the technology. If the end product is a fundamental improvement in military operations, then a revolution in military affairs is said to have occurred[3].

| Innovation | Decisive Event | Military Affairs |
|---|---|---|
| Infantry | 1346 Battle of Crècy | Infantry-cavalry combined arms. Longbow and pike. Dismounted English army defeats French cavalry three times its size. |
| Musket | 1449-53 Normandy Reconquest | Cannon and artillery destroy siege fortifications. Charles VII creates effective artillery army and expels English from France. |
| National Mobilisation | 1800 War of the Second Coalition | Universal conscription and social mobilization, combined with nationalism and modern industrial logistics. |
| Industrial Age I | 1866 Prussian victory over Austria | Steam power, railroad, and telegraph improve communications and logistics, while the rifle replaces the musket. |
| Industrial Age II | 1914 Marne | Mass production increases supply of war resources, rifle and machine guns produces total war and stalemate. |
| Industrial Age III | 1941 Pearl Harbor | Internal combustion engine, radio and aircraft design reintroduce mobility and manoeuvre. |
| Nuclear | 1945 Hiroshima | Nuclear fission couple with jet propulsion and rocketry to permit total and instant destruction of the state. |

**Table 1: Characteristics of Selected Historical RMAs[4]**

## Defining the Specific

The current RMA is a product of the information revolution and the technological advancements resulting from it. As such, today's revolution is not a product of a single scientific achievement, but of a greater technological revolution, entailing a package of new improvements, each one complementing the others and further expanding the possibilities for additional technologies. The information revolution of the 1990s led many to believe that a new RMA would be forthcoming, much as the industrial revolution had brought about significant military improvements. In particular, information technology could allow greater penetration of Clausewitz's 'fog of war', thereby imparting the RMA force with what has been variously dubbed "dominant battlespace knowledge", "total situational awareness", or, more superciliously, "a God's-eye-view"[5].

The fundamental goal of the RMA is to achieve and maintain perfect knowledge of the battlespace using improvements in information technology, namely a systemic interaction of sensors, computers, communications and weapons, to collect, interpret, distribute and act on information (Figure 1). This occurs on a macro level (within the strategic $C^2$ architecture) and on a micro level (as an integrated part of individual weapons

[3] Adapted from Vipin Narang, Aidan Harris and Fanny de Swarte, *The Revolution in Military Affairs*. Unpublished monograph, United Nations Institute for Disarmament Research, 2001.
[4] Adapted from Goldman and Andres, op. cit., pp. 99-101.
[5] Michael Howard and Peter Paret (eds., trans.), Carl von Clausewitz, *On War*, (Princeton, NJ: Princeton University Press, 1976), p. 119. *Cf.* inter alia, Martin C. Libicki, "DBK and its Consequences", in Stuart Johnson and Martin Libicki (eds.), *Dominant Battlespace Knowledge* (Washington DC: National Defense University Press, 1995); Thomas McCabe, "The Counterrevolution in Military Affairs", *Air and Space Power Chronicles*, 11th May 1999; William Owens, "The American Revolution in Military Affairs", *Joint Forces Quarterly*, No. 10 (Winter 1995-96), pp. 37-38.

platforms). In striving towards this goal, the RMA aims to produce a military that is able to meet any objective swiftly and efficiently while minimising losses and collateral damage. This requires that the component systems are both exceptionally accurate and extremely fast[6]. The result is an expansion to and utilisation of five battlespace dimensions: land, sea, air, space, and cyberspace. The ultimate goal is an efficiently synthesized, synergistic interaction of military systems, including all branches of the armed forces, into a single machine with the ability to project overwhelming power into any theatre[7].

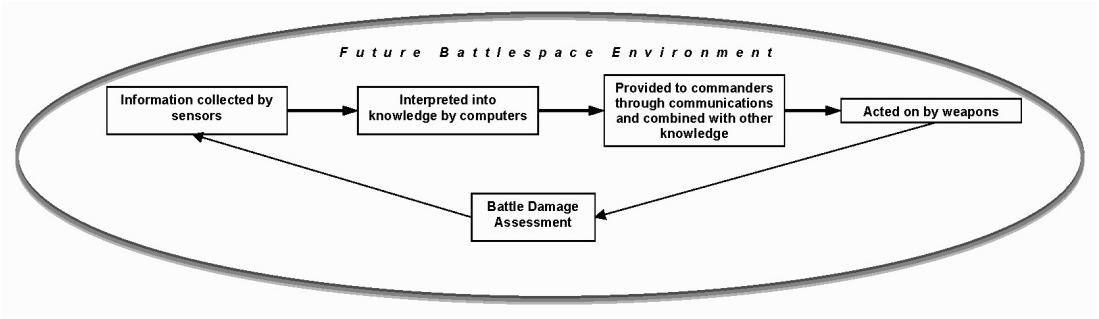


**Figure 1: Information Processes behind Dominant Battlespace Knowledge in the RMA**

It is important to note here that the RMA is a *hypothesis* (regardless of any degree of realisation) and not a process, identifiable group of technologies, or status quo. This can open up a semantic minefield when referring to "an RMA force" or "after the RMA". Similarly, we must distinguish between what is *an* RMA and *the* RMA, the former being generic and the latter specific to the contemporary, according to the two definitions presented above.

## An Evolution in Military Affairs

There are those who believe variously that the RMA has occurred, is in the near or distant future, or that the concept is a myth and that military innovation merely continues along a perpetual continuum. I take the position that technological progress to date, and anticipated near-future innovations, favours the conclusion that we are witnessing no more than an evolution in military affairs (EMA). Michael O'Hanlon, of the Brookings Institution, has written several sober critiques of military technological innovation and observes:

[6] As intelligence is a perpetually fluctuating factor, the RMA requires that all components operate in near-real time so that there is no lag time between taking a decision and that decision being executed.
[7] Narang, Harris and de Swarte, op. cit.

> [D]iscontinuously rapid changes in lethality, concentration of forces on the battlefield, or other basic characteristics of warfare could justify using the term revolutionary to describe ongoing progress. But if trends that have been underway for centuries, and that have been rapid throughout at least the last two centuries, simply continue, that may not be enough to make them historic or justify radical changes in warfighting tactics and strategy.[8]

There are numerous reasons for cynicism. Much of the technology seen in modern warfare is only incrementally better than previous versions. As Martin Libicki, of the National Defense University, points out, the improvements "are of degree and not of kind"[9]. Moreover, there remains no sufficiently large-scale war in which these systems can be truly tested, while technology and materials themselves may be reaching the limits of the laws of physics. However, of greater concern, there are numerous instances of failures, shortcomings and vulnerabilities that have not been adequately addressed.

Many critics of the RMA hypothesis, such as O'Hanlon and Libicki, concentrate on the term 'revolution' as a misnomer, and contend that truly revolutionary technology must entail more than we can see thus far[10]. However, it is my belief that we should give equal scrutiny to the viability of the term 'military affairs'[11]. The technologies that constitute the so-called RMA – such as stealth and smart weapons – were developed some decades ago, under the aegis of the Cold War necessity. Technologies emerging today were on the drawing board twenty years ago; Lawrence Freedman points out that "most of the core technologies associated with the RMA could be listed by the early 1970s"[12]. They were designed to defeat a regular, conventional army, symmetrically opposed in an open battlefield. This they did, with remarkable effect, in the deserts of the Persian Gulf in 1991.

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[8] Michael O'Hanlon, "Beware the RMA'nia!" (Washington DC: Brookings Institute, 1998). Paper presented at the National Defense University, 9th September 1998. http://www.brookings.edu/dybdocroot/views/articles/ohanlon/1998ndu.htm, accessed 9 August 2001.
[9] Martin C. Libicki, "Technology and Warfare", in Patrick Cronin, *2015: Power and Progress* (Washington DC: National Defense University Press, 1996), p. 120.
[10] *Cf.* Michael O'Hanlon, *Technological Change and the Future of Warfare* (Washington DC: Brookings Institute Press, 2000).
[11] The term 'military affairs' is used throughout this paper as a unit of analysis, describing the prevailing nature of warfare and dominant security themes.
[12] Lawrence Freedman, *Adelphi Paper 318: The Revolution in Strategic Affairs* (Oxford: Oxford University Press, 1998), p. 21.

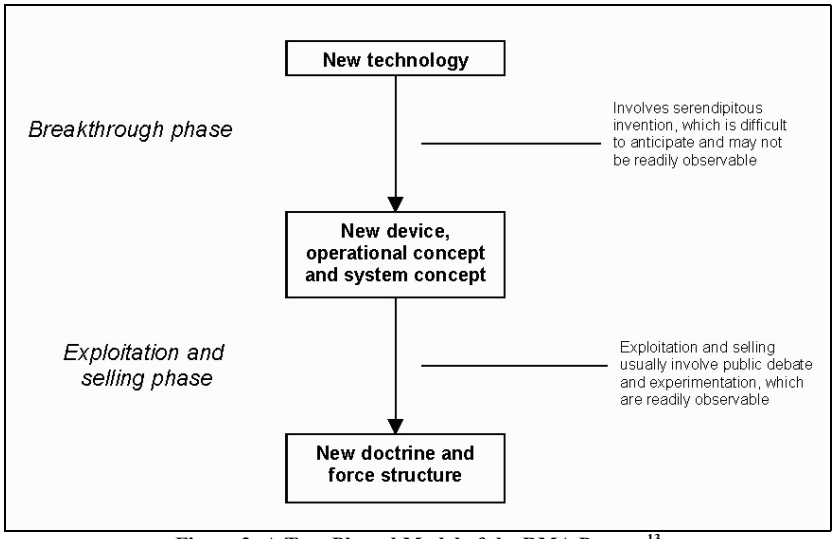


**Figure 2: A Two-Phased Model of the RMA Process**[13]
This model suggests that the current phenomenon is in the second phase.

The introduction of the longbow to 16th century forces may be considered an RMA because warfare was a far simpler phenomenon than it is now. Then, campaigns of territorial conquest carried the day. This paradigm briefly gave way to colonial concerns of native unrest within governed territories, but emerged again with the imperial wars of the late nineteenth century and World Wars. The Cold War held in place the view of territorial defence, re-conquest and liberation as the primary mission of armed forces. However this has given way to a new, chaotic security environment, in which militaries conduct peacekeeping, enforce stability, provide humanitarian relief, and combat international terrorism. The legacy forces of the Cold War, perfected by 1991, are rendered anachronistic by these new complexities. Just as an RMA was being reached in 1991, the paradigm under which it was devised was collapsing.

Sometimes, an RMA will force a paradigmatic shift in military affairs – as happened in 1945 with the nuclear RMA. Other times, evolving military affairs will render previous RMAs obsolete, creating demand for new military technology. Therefore, it is my contention that the capabilities demonstrated by US forces in 1991, were truly an RMA for the Cold War age. If security concerns had evolved in parallel with technology, these forces would still be revolutionary. However, the new security environment has moved the term 'military affairs' away from symmetrical engagements in open battles towards far more complex operations against obscure enemies, as demonstrated by the 'War on Terrorism'.

[13] Richard O. Hundley, *Past Revolutions Future Transformations* (Santa Monica, CA: RAND Corporation, 1999), p. 25.

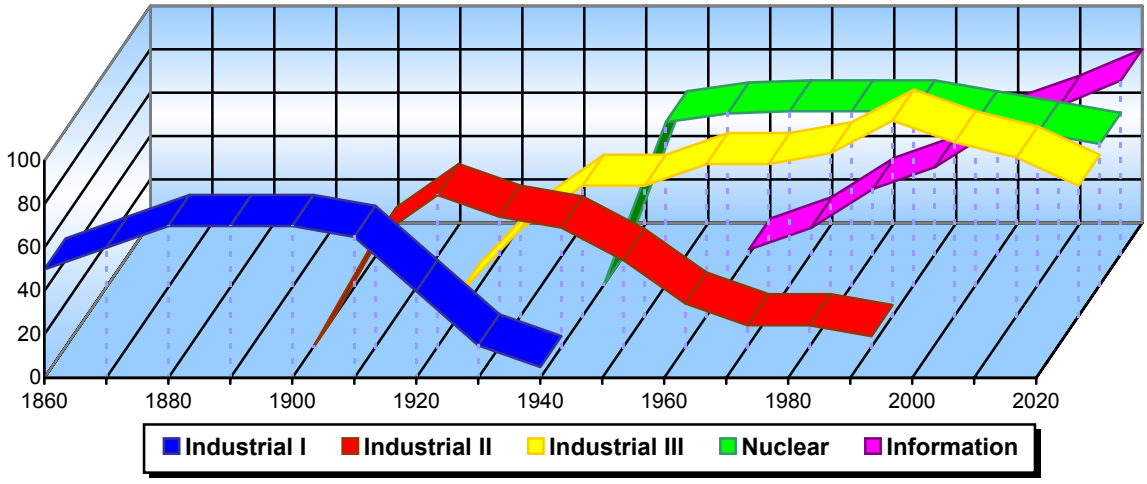


**Figure 3: The Rise and Fall of RMAs 1860-2020**[14]
Correlation of historical RMAs with the prevailing 'military affairs' paradigm (notional units), where military affairs = 100

Figure 3 suggests how RMAs need not be linear, sequential or mutually exclusive. For example, the nuclear RMA is one that gained ascendancy rapidly after 1945 and is likely to remain relevant until such time that nuclear weapons become obsolete. The first Gulf War saw the improvements made in the third industrial RMA throughout the Cold War, combined with a handful of early elements of the information RMA. Furthermore, the air-land battle of the third industrial age, having peaked in 1991, is in decline relative to military affairs in the twenty-first century. The nuclear RMA remains prevalent and concurrent with conventional systems, while information dominance is in ascendancy. Many believed that decisive strength in the 1990s was proof of the arrival of the new RMA, because of the corresponding convergence of the industrial legacy and information systems. However, as we progress deeper into the twenty-first century, changing military affairs are forcing the increased significance of information in warfare, and as such the convergence of late-industrial and early-informational systems cannot be considered revolutionary, in the light of this continuing transformation.

As an evolution in military affairs, technology is following the security environment, and for this reason we must continue to invest in future technology to meet today's demands. Today's technological output, and that of the near-future, will remain mostly embedded in the old paradigm. It is because the security environment has changed that new and emerging technologies are not revolutionary. They have emerged too late, and security dynamics have changed too much, to be so.

[14] Author's estimations of applicability of RMAs to military affairs. RMA types based on categorisations in Table 1, and presented here as degree of exploitation and not hypothetical potential. 'Military affairs' here are presented as a constant at 100 (notional units).

## Definitions and Limitations of Enquiry

The concentration of this paper will be on the US military as the most technologically advanced military power, with the greatest capacity to implement innovation, the most likely to be militarily active in the near-future, and whose actions (or lack thereof) carry the greatest potential geopolitical implications. The near-future time frame considered here is taken to mean a period of roughly twenty years hence. This is an approximation of the time in which feasible technologies in the laboratory today can be expected to enter into regular active deployment in the military. Furthermore, a twenty-year period is about the extent to which developments in geopolitics and the security environment can be reasonably anticipated. Additionally, I will omit analysis of strategic utility of emerging technologies, and concentrate in the main on their tactical and operational application. The progression of military innovation suggests that we are witnessing an EMA rather than an RMA, and therefore I do not believe that a near-future time frame will witness rapid strategic revolution.

Finally, the focus of study will be on military operations in urban terrain (MOUT). This is a capability in which modern forces remain alarmingly deficient, as many current technological advantages are rendered redundant in urban combat. Additionally, it is a combat scenario in which the US is likely to become more involved in the near-future as cities are increasing in number, size, and importance. The military is being increasingly tasked with operations other than war, in which urban operations are likely to be necessary. While the evidence does not suggest that an RMA is imminent, the under-investment in urban combat preparedness over the last twenty years, and the promise of emerging tactical technologies, suggest that there is great potential to improve urban military operations.

# Why Urban Operations?

## The Primacy of Cities

Today, around 3 billion people – half of the world's population – live in urban environments. Shanghai and its suburbs alone are home to 125 million people, and a police force approaching the size of the US Marine Corps[15]. By 2025, the world's urban population will have almost doubled. Over the next thirty years, world urban population will increase by an average of 180,000 people per day[16]. Demographic data show that the growth of urban centres is most prevalent in the developing world, where simultaneously there is great potential for instability (Figure 4)[17]. Rural-urban migration, particularly prevalent in the developing world, results in enormous urban populations without sufficient employment opportunities, leading to poverty, hostility and violence. Russell Glenn, a theorist with the RAND Corporation, notes the relationship between urban population growth and instability:

> Only three of the world's ten largest cities were in developing nations five years after World War II. By 1990, seven of the top ten were Third World cities. In late 1993, seventeen of the twenty-five most populous cities in the world fell into that category. The inability of some governments to handle the social, infrastructure, cultural, and myriad other problems makes their cities potential sources of unrest[18].

Cities are key political, economic and industrial centres, with transportation nodes, critical infrastructure, and significant symbolic importance for national morale. In much of the developing world governments concentrate their national power within one or two cities, adding strategic importance to their control. For an expeditionary military, the control of cities will be vital to secure port facilities, airfields and communications infrastructure. The primacy of cities is increasing, particularly in areas of instability, and with it the locus of conflict is shifting from the battlefield to the streets.

[15] Lester W. Grau and Jacob W. Kipp, "Urban Combat: Confronting the Spectre", *Military Review*, Vol. LXXXIX No. 4 (July-August 1999), pp. 9-17: p. 12.
[16] United Nations Population Information Network, *World Urbanization Prospects: The 1999 Revision* (New York: United Nations, 1999), p. 2.
[17] Ibid., p. 1.
[18] Russell W. Glenn, *Combat in Hell: A Consideration of Constrained Urban Combat* (Santa Monica, CA: Rand Corporation, 1996), p. 3.

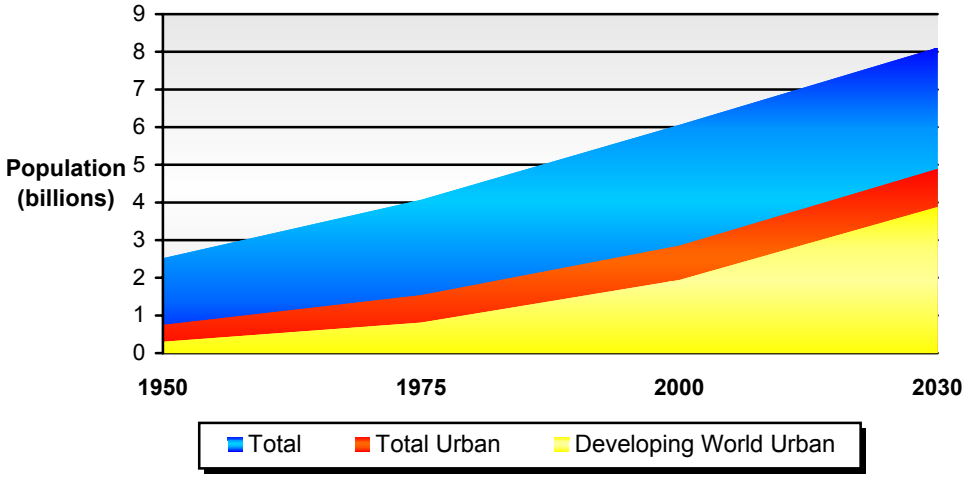


**Figure 4: World Population Trends 1950-2030**[19]
The majority of world urban population increase will be in the developing world, where growth will be six times that of cities in the developed world.

## Frequency of Involvement

The United States military has been active in urban environments numerous times in the last twenty years. 237 out of the last 250 Marine Corps overseas deployments have involved urban operations[20]. While the preference is to avoid urban combat where possible, US forces have seen action in Beirut, Panama City, Kuwait City, Mogadishu, Haiti, Sierra Leone and most recently, Baghdad. The accounts of each of these examples provide today's commanders with valuable lessons for the future. Moreover, there are good reasons to believe that the United States will become more involved in urban operations than it has in the past. In addition to the growing size and importance of cities, *Desert Storm* illustrated that enemy forces cannot compete with the US in a conventional open battlefield. To attempt to negate the advantage of a technologically advanced military, future enemies will place their troops and assets in urban environments to draw in vulnerable US forces[21].

### Types of MOUT

An MIT-sponsored conference in April 1999 identified three indistinct categories of MOUT: Policing operations, sustained combat, and raids[22]:

[19] Statistics based on UNPIP, *World Urbanization Prospects*, op. cit., p. 2.
[20] Russell W. Glenn, *Marching Under Darkening Skies: The American Military and the Impending Urban Operations Threat* (Santa Monica, CA: Rand Corporation, 1998), pp. 2-3.
[21] Daryl G. Press, *Conference Summary Urban Warfare: Options, Problems, and the Future* (Cambridge, MA: Massachusetts Institute of Technology). Unpublished monograph, January 1999. http://web.mit.edu/ssp/Publications/confseries/urbanwarfare/urbanwarfare.html, accessed 19th March 2003.
[22] Ibid.

Policing operations are typically of low intensity, where, although rules of engagement (ROE) are strict, opponents are uncoordinated, poorly motivated and lightly armed. The purpose of policing missions is to project a presence, rather than achieve objectives, and consequently these missions tend to be protracted. Policing missions are intended to promote values such as the rule of law, rather than protect strategic interests[23]. Given a propensity to avoid mundane policing duties around the world in the 1990s, and a preference for capabilities-based burden-sharing within alliances, we are unlikely to see the United States involved in policing operations in the near-future[24].

The catastrophic experiences in Berlin and Saigon, coupled with observations of Russian operations in Grozny, have made all-out war in cities anathema to US forces, unless vital to the national interest. In such circumstances it is likely that US forces will enjoy less restrictive ROE owing to the imperative of the mission objective. The bleak maxim of 'destroying a city to save it' is often used as a rationale for unchecked destructive force in total urban warfare. Where such instances do occur, they will be part of a strategic campaign rather than isolated missions. Furthermore, commanders undertaking sustained urban combat may well enjoy greater public and political support for such operations, as the stakes warrant.

Raids span the broad category between low-intensity and all-out war, thereby carrying the dangers of high risk coupled with sensitive mission restrictions. Raids include embassy evacuation, seizure of materiel, enemy search and arrest, and hostage rescue. Typically, raids involve the rapid insertion of troops, execution of the mission at the target site, and extraction before enemy forces are able to mobilise resistance. The key element is surprise, and rapidity of action ensures that this advantage is held.

While these categories provide convenient units of analysis for MOUT, they are deceptive in their simplicity. A more dynamic model is presented in the Marine Corps' concept of the three-block war:

[23] Ibid.

[24] This burden-sharing structure was seen in the NATO Kosovo campaign, where the United States preferred to conduct air operations in which it clearly held the superior capability, and other allies engaged in the (arguably) less technologically demanding role of peacekeeping duties. While it is true that the United States has been involved in numerous policing duties since 1991, these have usually been short–term engagements, often as a preparation for a multilateral task force. A clear example of this can be seen in the liberation of Kabul by US forces in 2002. In a war lead by the United States, American forces quickly handed control of peacekeeping duties to a Turkish force after a few months.

> In one moment in time, our service members will be feeding and clothing displaced refugees – providing humanitarian assistance. In the next moment, they will be holding two warring tribes apart – conducting peacekeeping operations. Finally, they will be fighting a highly lethal mid-intensity battle. All on the same day, all within three city blocks. It will be what we call the three block war.[25]

The three block war concept is designed to prepare the Marine Corps for the complexities of modern urban mission requirements. However, its relative novelty has meant that its doctrinal utility has not yet been fully appreciated (see later section).

## Difficulties of MOUT

The RMA hypothesis envisages a synergistic force structure, where differing capabilities from all branches of the armed forces interact. However, the apparent redundancy of many of the systems inherent to the current force significantly impairs comparative effectiveness in an urban environment. Drawing US forces into a hostile city for urban combat is not an asymmetric tactic. The United States is -- demonstrably since 1991 -- and will remain in the near-future, an asymmetric force because of precision and dominance in conventional battle. Rather, engaging in an urban environment is to level the playing field, to make the confrontation more symmetrical[26]. In cities, conflict is reduced to rifle versus rifle; urban battles are conducted street-by-street, building-by-building and even room-by-room. In cities, adversaries can seek a greater semblance of parity.

The physical construct of the urban environment immediately adds to the fog and friction of warfare. Buildings in developing world cities are of crude construction, made of materials that provide inadequate protection from bullets, or blow over from helicopter rotor blades. Streets may be haphazard, unpaved, flooded, with little by way of local infrastructure to make use of. By contrast, modern metropolises hold ever more hiding places for the enemy, with skyrises and subway systems. In a 1997 exercise, for example, experts calculated that it would take 62 infantry battalions 18 months to clear a twenty block area of high-rise downtown Seoul[27]. MOUT units must navigate and dominate the enormous volume of the battlespace, rather than the two-dimensional area of the open battlefield. Furthermore, cities give natural advantage to the defender. Intricate local knowledge and myriad means of concealment enhance the defender's tactical advantage.

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[25] Charles C. Kurlak, "The Strategic Corporal: Leadership in the Three Block War," *Marines Magazine* (January 1999), p. 30.
[26] Russell W. Glenn, *"...we band of brothers": The Call for Joint Urban Operations Doctrine* (Santa Monica, CA: Rand Corporation, 1999), p. 8.
[27] This estimate assumed a favourable casualty rate of 10 to 1, an average of ten seconds to clear a room, and that the opposing forces would continue to defend without supplies or surrender over the 18 month campaign. Robert K. Ackerman, "Echoes of Chechnya Warfare Resound in Moscow, Quantico", *Signal Magazine*, (May 2000).

### Vehicular Manoeuvre

Whereas on open battlefields, mechanized and armoured units can be used without hindrance, city environments provide a host of obstacles and difficulties. Central dividers, overpasses, tunnels, and weak bridges obstruct movement, chennelizing vehicles into labyrinthine streets, making routes predictable, and providing ideal conditions for ambushes and roadblocks[28]. This lesson was learned by Russian armed forces in Grozny in the mid-1990s, where units were lured into narrow streets and prevented from withdrawing or counter-manoeuvring by their own burning vehicles[29]. In the first three days of 1995, a single Russian column lost 20 of 26 tanks and 102 of 120 armoured vehicles[30]. Retreating Ranger forces in Mogadishu found that when vehicles stopped in convoy formation, those at intersections were dangerously exposed to enemy fire and unable to manoeuvre because of being blocked by units in front and behind[31]. The close proximity of multi-level structures next to armoured units allow hostile forces to use anti-tank weapons at angles that permit light antitank rounds to penetrate the generally thinner top armour of tanks and infantry vehicles[32].

### Aerial Support

The general scarcity of open spaces makes potential helicopter landing zones conspicuous, vulnerable and predictable[33]. Close air support is risky as helicopters are vulnerable to unseen portable enemy fire, and high altitude support is slower and less accurate, making it unsuitable to use on rapidly shifting formations of enemy fighters. While high-altitude aircraft can conduct effective strikes against targets in cities with precision-guided munitions as part of a strategic bombing sortie, these tactics are dangerous in fire-support missions for forces already on the ground. Heavy artillery barrages are of little use as artillery shells often fall at too shallow an angle to achieve an accurate hit[34], posing a threat to friendly forces on the ground and dramatically increasing the likelihood of collateral damage, rendering artillery largely unacceptable except in the gravest scenarios.

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[28] Barry R. Posen, "Urban Operations: Tactical Realities and Strategic Opportunities", in Michael C. Desch (ed.), *Soldiers in Cities: Military Operations on Urban Terrain* (Carlisle, PA: Strategic Studies Institute, 2001), pp. 149-166: p. 152.
[29] See Carlotta Gall and Thomas de Waal, *Chechnya: Calamity in the Caucuses* (New York: New York University Press, 1998).
[30] Timothy L. Thomas, "The Battle of Grozny: Deadly Classroom for Urban Combat", *Parameters*, Vol. 29 No. 2, (Summer 1999), pp. 87-102: p. 88.
[31] See Mark Bowden, *Black Hawk Down: A Story of Modern War* (London: Corgi Adult, 2000).
[32] Posen, op. cit., p. 151.
[33] Ibid., p. 152.
[34] Press, op. cit.

Furthermore, turning a city to rubble can greatly shift the advantage to the defender as new obstacles are created for the attacker[35].

### Infantry Impediments

For all of these reasons, MOUT is and will remain the troubled domain of the traditional foot-soldier. With multi-level structures, subterranean passages and narrow alleyways, infantry units must operate in a three-dimensional environment in which hostile forces may remain concealed in extremely close proximity, with an extraordinary number of potential firing positions[36]. Enemy infantry will generally enjoy the home advantage and be more knowledgeable of the city's population, assets and subtle characteristics. The enemy will be able to move in and through buildings in order to arrive at a target before advancing infantry forces, or escape confrontation.

Furthermore the dense concentration of above-ground structures in urban settings means that units may only have a few yards of line-of-sight for combat, thus losing the technological edge of accurate long-range fire. Combined with a high concentration of non-combatants, and the necessary disaggregation of friendly forces throughout the city, this propensity for close-quarters combat increases the risk of fratricide and civilian casualties. Indeed, the engagements may be of such close range that bayonets are necessary, and rifle bullets retain enough energy to penetrate body armour[37].

Battles in cities consume enormous resources, both personnel and materiel. America's recent experience and simulations suggest that a rifle company of 100-200 men can secure a defended city block in twelve hours, sustaining 30-45% attrition[38]. Compared with the improvements made in other weapons platforms during the Cold War years, the infantryman's technological assets have remained relatively static (Table 2), the most revolutionary being night-vision devices. In recent years however, with the increasing prevalence of MOUT and realization of a severe capabilities gap in the 1990s, emerging infantry concepts have received greater attention.

[35] Posen, op. cit., p. 154.
[36] Russell W. Glenn, Randall Steeb and John Matsumura, *Corralling the Trojan Horse: A Proposal for Improving U.S. Urban Operations Preparedness in the Period 2000-2025* (Santa Monica, CA: Rand Corporation, 2001), p. 4.
[37] Posen, op. cit., p. 153.
[38] Ibid.

| Aircraft | | Infantry | |
|---|---|---|---|
| **1945** | **1991** | **1945** | **1991** |
| Gravity bombs | Guided munitions | Rifle | Extended range and sights |
| Limited range | In-flight refuelling allows unlimited range | Helmet | Body armour |
| Subsonic speeds (~500mph) | Supersonic speeds (>1,600mph) | - | Night vision |
| Gyroscopic and radar guidance | GPS | | |
| - | Extensive avionics, onboard computer | | |
| - | Stealth | | |

**Table 2: Comparison of Improvements in Aircraft and Infantry 1945-1991**

The benefits of long range, stand-off expeditionary warfare, as perfected throughout the Cold War, are largely muted in MOUT. Moreover, many of the fundamental limitations of the RMA are particularly acute in urban settings. However, incremental improvements can be found in the near-future. Furthermore, as this is a capability that has long suffered neglect and under-investment, re-application of existing technology can be expected to yield significant results.

# PART TWO: Improving the Infantry's Inventory: An Assessment of New and Emerging Technologies

# Communications

Infantry operating in cities find that the 'urban canyon' obstructs their communications. Radio, which relies on line-of-sight for transmission, is impeded by interference from steel and concrete structures. Radios that are small and light enough to be carried by infantry rely on VHF and UHF bands, and near-future devices will predominantly be improvements on these technologies[39]. Cellular and satellite communications are not suited to MOUT as they require vulnerable fixed or civilian infrastructures, have low rates of data transmission, are susceptible to jamming and interference, or are not interoperable with other military systems[40]. However, they may be useful in more benign operations such as policing, where forces can be seen to be working closely and co-operatively with local civilian authorities. Notwithstanding these limitations, there are several innovations in communications technologies that could incrementally improve urban operations.

## Shrinking Radios and Expanding Bandwidths

The main scope for improvement lies in trends in the miniaturization of electronics and the increasing sophistication of software. The transition from analogue to digital radios will be completed in the next ten years, allowing for enormous amounts of data to reach large groups of units. These benefits were made evident in *Allied Force*, where software upgrades allowed warfighters to receive satellite data in minutes rather than hours[41]. However, the particular requirements of infantry again limit the advantage afforded to other weapons platforms. For example, tanks and aircraft are equipped with an integrated digital radio, GPS and computer package[42], but size and weight restrictions prevent similar equipment being used by infantry.

### Aerial Relays

The use of unmanned aerial vehicles (UAVs) as tactical relay systems presents a viable, if expensive, means of bridging gaps in line-of-sight transmissions[43]. UAV technology at present remains cumbersome: they are slow, highly vulnerable to enemy fire, and require ground support. However, many of these difficulties are surmountable in time,

[39] Rand Arroyo Center, Army Research Division, *Improving Communications in Urban Warfare* (Santa Monica, CA: Rand Corporation, 2002). http://www.rand.org/publications/RB/RB3029, accessed 20th March 2003.
[40] Ibid.
[41] O'Hanlon , *Technological Change*, op. cit., p. 53.
[42] Ibid.
[43] *Improving Communications in Urban Warfare*, op. cit.

through continuing improvements in performance. A micro-UAV capable of carrying more than 25lbs could act as a tactical communications relay over short distances, and these are likely to become an indispensable part of the infantry's inventory in the near-future[44]. They can be deployed inexpensively in great number to create a network that is inherently more survivable that its component parts. Their small size provides a limited cross-section to fire upon, making them more robust and discrete.

### Towards Networked Soldiers

In February 2003, DARPA announced it has provided soldiers with its Small Unit Operations Situational Awareness System (SUOSAS) [45]. SUOSAS uses peer-to-peer (P2P) transmission to create a secure, mobile network. The self-powered voice/data transmitters are carried with soldiers, and its P2P characteristics means that transmissions are shorter (to the nearest node), and more resistant to interference. The SUOSAS forms part of the Defense Department's (DoD) plan for an intelligent, robust, self-forming distributive battlespace network, enhancing situational awareness for both infantry and commanders[46].

### A Communications Revolution?

In the near-future further improvements in wide-bandwidth communications, digitisation and software upgrades will continue to enhance situational awareness in the urban battlefield. Additionally, the greater proliferation of aerial relays will help to alleviate problems such as fading and transmission black spots. Furthermore, enhanced power management and miniaturization will increase the portability of existing systems. While laser communications are comparatively novel, they are still subject to line-of-sight for operability, and performance in wet weather is worse than radar. Such advancements may hold advantages, for example, in naval warfare where clear lines of sight exist, but they will not help MOUT engagements[47]. While software based radios can help to improve signal strength and encryption, transmission is still reliant on radio technology that is almost seventy years old. However, software-centric radios will alleviate the problems associated with hardware upgrades, as software can be quickly and easily uploaded.

Moreover, video is all very well, but such information necessitates carrying a visual display and demands visual distraction[48]. Units in hostile territory will have a hard enough

[44] Ibid.
[45] Dan Caterinicchia, "DARPA 'Soldiers Radio' Bridging Gaps", *Federal Computer Week*, 27th February 2003.
[46] Ibid.
[47] O'Hanlon, *Technological Change*, op. cit., p. 54.
[48] Ibid., p. 53.

time watching out for threats all around them, without also having to watch video communications. The DoD is investing in infantry heads-up-displays, similar to those used by pilots for decades. However, it is quite clear that real improvements for the infantry must come in an integrated package: communicators, computers, visual displays, all in a man-portable package. The danger is that providing an improvement in one area, could easily degrade performance in another area without accompanied improvements.

Naturally, dependence on communications will lesson with effective improvements in situational awareness and intelligence at squad level. Units that do not have to call back to commanders for intelligence updates, enjoy greater mission autonomy and operational freedom. Empowering the individual soldier with greater information in the first place reduces his need to communicate, particularly when the information he receives is part of a networked web of intelligence that is shared at all levels.

We will not see any great leap forward in communications technology in the near-future. The improvements listed above are clearly evidence of the evolutionary nature of technological trends, and despite the incremental upgrades, we will not see the introduction of a wholly new communications technology.

# Innovations in Situational Awareness

The RMA is knowledge based, and therefore reliant upon the proper collection, analysis and dissemination of information from sensors (see Figure 1). While the RMA has been most evident in advances in airpower and smart munitions[49], as O'Hanlon observes, improvements for the infantry and urban warfare are less likely to be forthcoming because of the constraints on the performance of future battlefield sensors[50]. Improvement in these areas relies not so much on innovative new technologies, but on better application of existing ones. Sensors are limited by the laws of physics, which will remain insurmountable. Moreover, unlike in an open battlefield, physical structures obstruct the line-of-sight for radar and lidar technologies[51].

Intelligence in MOUT is dominated by situational awareness. While satellite imagery and signals intelligence may be useful in mission planning, the rapid dynamics of urban operations means that intelligence can become dangerously obsolete in hours or minutes. For the infantry unit, the greatest intelligence comes from real-time close-in sensors. Improvements in situational awareness therefore rest on developing more accurate, portable sensors, and the means with which to project them deeper into the battlespace. Infantry units come ready-equipped with the human sensorial functions providing unique perceptional awareness. However, new and emerging technologies may help to extend the range and depth of these capabilities.

## Sensors

### Acoustic

Handheld acoustic sensors could help to indicate the location of snipers, by using a directional technique similar to sonar[52]. However, the potential accuracy of such a device is limited by background noise, and might not provide much more information than a soldier could determine himself from impact[53]. Furthermore, the considerable difficulties in

[49] Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey*, Summary Report (Washington DC: Government Printing Office, 1993).
[50] O'Hanlon, *Technological Change*, op. cit., p. 33.
[51] Lidar (light detection and ranging) works along similar principles to radar (radio detection and ranging). Lidar sensors are active, rather than passive, emitting lasers and detecting reflections.
[52] O'Hanlon, *Technological Change*, op. cit.
[53] While an acoustic detection device could indicate the direction of fire from shots that miss, even a modestly trained sniper rarely misses a target.

eliminating a well-concealed and mobile sniper are unlikely to be overcome by sensors, and they will continue to hold MOUT forces at risk.

### Electro-chromatography

Sandia National Laboratory is currently developing microchip-sized chemical detectors. By applying multiple detection methods in a single electronic device, Sandia has built a self-contained 'laboratory microchip' in a device the size of a pocket calculator[54]. These would enable MOUT forces to search for, or avoid, explosives and other chemically identifiable substances, where current detection capabilities require lab analysis. While technologically more difficult, a biological agent detector is expected to be available in the next five years[55]. These technologies could be used on suspects to indicate whether they have been in contact with explosives. In March 2003, US soldiers were criticised for strip-searching captured Iraqi soldiers for concealed explosives. A handheld detector would allow forces to perform such searches more efficiently and with greater respect for detainees.

### Global Positioning System

GPS navigation has been commonplace for more than a decade, and its accuracy is increasing. In 1991, thousands of GPS receivers were used by the military, with accuracies of around 20 metres[56]. The DoD is due to replace the current GPS in 2004 with the Defense Advanced GPS receiver (DAGR), providing positional information in one-sixth of the time, using half the battery consumption and in a unit half the weight and two-thirds the size of older versions[57]. The DAGR also has a visual display to remove the burden of map plotting, and adds a second frequency, increasing accuracy, response time and resistance to jamming[58]. GPS can quite easily be rendered inaccurate within a 10-mile radius through jamming from a device constructed for $400 from retail stores[59]. For example, in 2000, British Challenger and US Abrams tanks on joint exercise suffered from navigational problems. It was discovered that the signals were being jammed by French systems hidden on the testing range[60]. While the DAGR upgrade will certainly enhance situational

[54] Gerald Yonas and Timothy Moy, "Emerging Technologies and Military Operations in Urban Terrain", in Michael C. Desch, *Soldiers In Cities: Military Operations on Urban Terrain* (Carlisle, PA: Strategic Studies Institute, 2001), pp. 131-138: p. 133.
[55] Ibid.
[56] Thomas K. Adams, "GPS Vulnerabilities", *Military Review*, Vol. LXXXI No, 2 (March-April 2001), pp. 10-16: p. 11.
[57] Christian B. Sheehy, "New GPS Handheld Receiver Planned for '04", *National Defense Magazine*, (February 2003).
[58] Ibid.
[59] Adams, op. cit., p. 14.
[60] Lester W. Grau, "GPS Signals Jammed During Tank Trials", *Military Review*, Vol. LXXXI No, 2 (March-April 2001), p. 12.

awareness, it will only be a matter of time before the commercial technology is available to disrupt the new systems.

### Identify Friend or Foe

The highly valued 'identify friend or foe' (IFF) system could prevent fratricide in MOUT. The IFF is clipped to the end of an M-16, and indicator lights tell the soldier whether the target is a friend -- or, more accurately, whether the target is wearing an interoperable IFF transmitting system. The IFF does not distinguish between enemy and non-combatant, or for that matter, friendly forces that do not have IFF technology[61], posing considerable problems when operating alongside a multinational or joint task force, or with local civilian authorities. Furthermore, there are unsettling dangers in reducing the decision to fire to a red or green indicator light. Whereas the IFF on aircraft indicates status on visual tracking systems, the subtle difference with rifle IFF is that indicators are given when taking aim in preparation to fire. Commanders will be anxious to ensure that IFF does not affect or replace individual judgement, which then raises the question of whether such systems are necessary in the first place.

## Drones, Remotes and Robots

While sensors can be carried by the infantry, their range is limited by the unit's location. MOUT forces require the organic capability to operationally deploy remote systems according to their situational requirements, in order to extend their range.

### Unmanned Ground Vehicles (UGVs)

DARPA has developed a UGV, nicknamed 'Urbie', with swing arm tracks that allow it to climb stairways autonomously. Equipped with stereo and omni-directional cameras, as well as navigational gyroscopes and GPS, the Urbie can move autonomously after being given commands by an operator. Furthermore, the Urbie features intelligent electronics that can avoid obstacles, navigate to an identifiable target, and remain in shadow[62]. However, despite having exceptional sensory perception, the Urbie is still a tele-operated vehicle and its operator must interpret the information it gathers[63]. This is a disadvantage when personnel in the field may be fighting running battles and do not have the time to direct a remote vehicle. However it could prove useful in low intensity military

[61] Roxana Tiron, "Urban Exercise Tests Novel Technology", *National Defense Magazine*, (November 2002).
[62] Thomas Goodsell and Magnus Snorrasson, "Situational Awareness and Unmanned Ground Vehicles", *World Defence Systems*, Vol. 4 No. 3 (December 2002), pp. 64-69: p. 68.
[63] Ibid.

operations such as traversing minefields, and a prototype was used to assist search and rescue at the World Trade Center in 2001[64].

The Dragon Runner UGV was specifically built for organic urban intelligence from commercial technologies to minimise costs. The system had to be light, deployable in seconds, inexpensive, and reusable yet expendable[65]. While the Dragon Runner cannot climb stairs, it is light enough to be thrown through upper floor windows, and fully invertible so no matter what side the vehicle may fall on, so it keeps its direction and transmits images according to plan[66]. The Dragon Runner weighs only nine pounds, can last for 24 hours on a standard infantry radio battery, and is capable of speeds of 25mph. A second-generation prototype is expected to be ready by summer 2003[67]. While its vulnerability does not sit well with its current cost of $12,000, even vulnerability can have its uses: a Dragon Runner that is destroyed serves the purpose of drawing fire and indicating the presence of the enemy. Rather than try to increase its survivability, it is hoped that the cost can be halved to make the unit effectively expendable[68].

### Unmanned Aerial Vehicles

Micro-UAVs are being developed to give the infantry an organic aerial option that would be able to fly within buildings or underground passageways and transmit data back to field users[69]. The Dragon Eye UAV weighs five pounds and its modular assembly allows it to be carried in a backpack. Last year, the Marine Corps received forty Dragon Eyes for evaluation, and, at a cost of up to $70,000 each, and are planning to purchase 311 Dragon Eyes by 2006. With a range of five kilometres and 45 minutes flight time[70], Dragon Eye could perform tactical reconnaissance where the larger UAVs are unsuitable. Furthermore, as an autonomous vehicle, the Dragon Eye needs only to be programmed to fly in a holding pattern rather than be remotely piloted[71].

### Vivisystems

What may seem like an absurdly distant concept is the possibility of using insects as swarming sensors. Researchers at Sandia have successfully conditioned bees to detect

[64] Ibid., pp. 68-9.
[65] Dave Moreau, "Dragon Runner: Situational Awareness for Small Units", *World Defence Systems*, Vol. 4 No. 3 (December 2002), pp. 50-53: p. 51.
[66] Tiron, "Urban Exercise Tests Novel Technology", op. cit.
[67] Moreau, op. cit., p. 53.
[68] Tiron, "Urban Exercise Tests Novel Technology", op. cit.
[69] Glenn, Steeb and Matsumura, op. cit., p. 16.
[70] Cindy Fisher, "KBX Explores Emerging 21st Century Technology", *Marine Corps News*, 28th June 2001.
[71] Ibid.

explosives in concentrations below twenty parts per billion, by combining sugar-water with traces of TNT[72]. Furthermore, DARPA has funded a Sandia project to develop a tracking chip that weighs less than 1mg, has a self-contained antennae, and is approximately the size of a grain of salt[73]. The use of bioswarms as sensors is a distant possibility, although performance is limited by environmental constraints such as rain, temperature and light, as well as natural sensorial instincts. (In this way, an insect could be subject to jamming and interference to the same effect as electronic equipment, by simply using stronger scents to lure the insects to an alternative location). However, there does not appear to be a viable long-range chemical sensor available in the near-future, and while vivisystems may present numerous problems in themselves, they may be the only means of detection of such agents.

### Networks and Webs

The Pentagon is developing the Smart Sensor Web (SSW) Initiative to combine and co-ordinate the sensor intelligence from across the services into one network. The establishment of network-centric warfare would represent a truly exponential improvement in the co-ordination of all aspects of military affairs, and is an integral part of the information RMA. The SSW calls for the dispersion of smart sensors throughout the battlespace integrated into a single network to provide a wider picture to commanders than is currently available[74]. The combination of sensors across the technological spectrum, at all levels of operations and across all services is certainly an ambitious task, but there is little doubt that its benefits would bring commanders closer to the coveted "God's-eye-view" that they seek. While such an initiative is necessarily larger than the confines of the MOUT environment and the infantry unit, a multi-dimensional and multi-spectral mapping of the urban battlefield would obviously improve situational awareness[75]. However, in addition to the fundamental obstacles of co-ordination and management of such a network (the bandwidth and computational power required is exorbitant), its effectiveness would be necessarily as good as the individual sensors, and for this reason the emphasis of this paper is on primary technological innovation and not compound improvements.

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[72] "Bees to 'Sniff Out' Explosives", *BBC News Online*, 14th May 2002, http://news.bbc.co.uk/1/hi/sci/tech/1986769.stm, accessed 9th November 2002; also "Sandia, University of Montana Researchers Try Training Bees to Find Buried Landmines", Sandia National Laboratories News Release, 27th April 1999. http://www.sandia.gov/media/minebees.htm, accessed 20th March 2003.

[73] Tim Schaefer, "Development of Micro-Miniature Transceiver for the Identification and Tracking of Various Insect Species (Grain of Salt)", DARPA Controlled Biological Systems Project, http://www.darpa.mil/dso/thrust/biosci/cbs/mayo_ab.html, accessed 19th March 2003.

[74] Bryan Bender, "DoD Eyes Sensors to give 'Urban Canyon Visibility'", *Jane's Defence Weekly*, 16th February 2000.

[75] Glenn, Steeb and Matsumura, op. cit., p. 17.

## Casualty Aversion and Non-Lethality

As a casualty averse power, the United States is particularly sensitive to excessive or unnecessary casualties, foremost among its own forces, but also among friendly forces, non-combatants and even enemy forces. Casualty phobia has increased as technology has made war seem more clinical and bloodless, with increased accuracy in both information and weapons. This effect has combined with the pervasive products of globalisation as the media has unprecedented access and audience in modern conflict[76]. While the motives for intervention in Somalia were almost exclusively humanitarian, and resulted in many more lives saved than taken, images of US soldiers shooting the people they came to rescue led inexorably to accusations of heavy-handed imperialism. The decision to use lethal force is now a strategic as well as tactical one, because of the consequences for public opinion. RAND theorist Sean Edwards notes this trend:

> There seems to be a greater concern over noncombatant casualties than in the past. […] Tolerance levels are changing because the new weapons are believed to be more surgical. Adversaries have tried to capitalize on this sensitivity to bloodshed. The human shield tactics witnessed recently in Iraq and the Balkans prevented the use of airpower when civilians positioned themselves on strategic targets like bridges.[77]

The conundrum for the United States is obvious: tolerance for casualties is low while the probability of urban combat is high[78]. The Achilles Heel of the United States is political: it is on Capital Hill and CNN where the US will be defeated, not on the battlefield. As such, potential enemies can gain massive advantage by exploiting the ROE that restrict MOUT forces.

### The Rules of Engagement

The ROE dictate the conditions and proportionality governing the use of force, and are designed to ensure that force is not used arbitrarily. A study by the RAND Corporation noted "an inverse relationship between the amount of firepower used and friendly casualties: the more firepower applied to a built-up area, the lower the friendly force's losses" but with

[76] This phenomenon represents a different type of revolution in the affairs of the military. Embedded journalism – reporters stationed with active duty troops – meant that live images and running commentary of fierce firefights on the outskirts of Umm Qasr could be transmitted directly to global audiences. In addition to the normative shock effect that this may have on the public, this access has removed the military's control of war information.
[77] Sean J. A. Edwards, *Mars Unmasked: The Changing Face of Urban Operations* (Santa Monica, CA: Rand Corporation, ), p. 44.
[78] Glenn, Steeb and Matsumura, op. cit., p. vii

the caveat that this comes at the expense of higher non-combatant fatalities[79]. Urban ROE, therefore, are often reduced to assessing the value of American lives in terms of the lives of non-Americans.

When facing an irregular militia, innocent and enemy become indistinguishable, particularly under stressful urban conditions. In MOUT environments, the local populace is often unable or unwilling to leave the city, and the high density of non-combatants significantly inhibits operational freedom. There are primarily three methods to reduce non-combatant casualties and circumvent this restriction:

i) Better relations with the local population, to alienate them from the enemy and encourage them to stay away from battles;
ii) Use of psychological operations (PSYOPS) to achieve like objectives;
iii) Greater application and availability of non-lethal technology[80].

### Non-Lethal Technologies

Clausewitz observed that the aim of warfare was not to kill as many of the enemy as possible, but to "render him powerless"[81]. Lethality in warfare is only a consequence of using available force options to ensure force protection in achieving mission objectives. With this in mind, modern militaries are looking at how force can be applied in a less-than-lethal way.

In July 1996, the DoD issued a non-lethal weapons policy, defining as non-lethal those "explicitly designed and primarily employed so as to incapacitate personnel or materiel, while minimising fatalities, permanent injury to personnel, and undesired damage to property and the environment"[82], and established the Joint Non-Lethal Weapons Directorate (JNLWD), under the command of the Marine Corps.

Some advocates claim that proper employment of non-lethal weapons (NLWs) would effectively remove the body bag from the battlefield. A more probable conclusion would be that NLWs could be suitable in situations where lethal force may not be necessary, or where there is increased risk of unintended casualties. The very spectrum of non-lethal

[79] Ibid.
[80] Peter J. Gulliver, *By the Edge of the Sword: A Consideration of the Challenges Inherent in Modern Urban Military Operations*. Unpublished monograph, Yale University. http://www.urbanoperations.com/swordsedge.htm, accessed 5th March 2003.
[81] Howard and Paret, op. cit., p.77 and *passim.*
[82] U.S. Department of Defense Directive Number 3000.3, *Policy for Non-Lethal Weapons* (Washington DC: Government Printing Office, 9th July 1996), p. 2, Section 3.1.

technologies would provide huge tactical flexibility and greatly increase the individual soldier's operational freedom (Table 3)[83].

| Type | Category | Example | Effects | Uses |
|---|---|---|---|---|
| **Anti-personnel** | Kinetic | Rubber bullets | Blunt impact trauma | Used in crowd control since the 1960s |
| | Chemical | CS spray | Skin irritation, temporary incapacitation | First used in 1968 Washington riots |
| | Acoustic | Infrasound | Biophysical effects: nausea, disorientation, organ damage, blunt object trauma | No known uses. A 10Hz Russian device is though to exist |
| | Barrier | Superadhesives | Rigid or sticky foam used to inhibit movement | Used in Somalia, 1995 |
| | Optical | Laser Dazzle System | Blinds optical sensors | Used by Royal Navy in 1982 |
| **Anti-Materiel** | Electro-magnetic | High powered microwave | Disrupts electronic systems | Reportedly ready for use against Iraq in 2003 |
| | Conductants | Carbon-fibre munitions | Short circuits electrical systems | Used in Belgrade 1999 |
| | Reactants | Liquid Metal Embrittlement | Alteration of molecular structure of base metals and alloys, leading to material degradation | No known uses |
| | Virtual | Electronic viruses | Disables or disrupts infected electronic systems | A clandestine virus was used to disrupt the Iraqi air defence system in 1991 |

**Table 3: Examples of Selected Non-Lethal Technologies[84]**

A capabilities gap has emerged in which US forces are simply unable to meet the casualty averse political demands of their mission. In addition, a vulnerability gap exists, as enemies exploit this deficiency. A raiding force convoy, for example, could be delayed by streets packed with civilians, allowing their targets time to escape. Marines in Somalia complained of opportunist thieves stealing their equipment, knowing that the Marines were not allowed to shoot them[85]. Somali clansmen used women and children as shields against US Rangers[86], and Iraqi and Serbian forces placed civilians around military targets to deter air strikes[87]. Not only did this inhibit freedom of action tactically, but also endangered force protection as viable targets could not be identified. In 1995, Operation United Shield saw the return of US Marines to Somalia, this time armed with "riot control agents, low-kinetic-energy rounds, the Saber 203 dazzler [and] sticky foam"[88]. Intelligence reports indicated that

[83] For an excellent, if now somewhat dated, comprehensive glossary of developmental and theoretical non-lethal technologies, see Robert J. Bunker, *Occasional Paper 15: Nonlethal Weapons: Terms and References*, (USAF Academy, CO: Institute for National Security Studies, 1996); also Committee for an Assessment of Non-Lethal Weapons Science and Technology, *An Assessment of Non-Lethal Weapons Science and Technology* (Washington DC: National Academies Press, 2003).
[84] Sources: Robert J. Bunker, op. cit., *passim*; Richard Kokoski, "Non-Lethal Weapons: A Case Study of New Technology Developments", *SIPRI International Yearbook* (Stockholm: SIPRI, 1994), pp. 367-386; Morris and Morris, op. cit.; Dennis B. Herbert, "Non-Lethal Weaponry: From Tactical to Strategic Applications", *Joint Forces Quarterly*, No. 21 (Spring 1999), pp.87-91: p. 89.
[85] Herbert, op. cit., p. 88.
[86] See Mark Bowden, *Black Hawk Down*, op. cit., *passim.*
[87] See Anthony Cordesman, *Key Targets in Iraq* (Washington DC: Center for Strategic and International Studies, February 1998), p. 15.
[88] Committee for an Assessment of Non-Lethal Weapons Science and Technology, op. cit., p. 53.

warlords were planning to use mob tactics against the Marines, but following the dissemination of information about the new weaponry in the local press, the mobs failed to materialise[89].

### Directed Energy Weapons

Directed energy weapons (DEWs) use the electromagnetic spectrum to propel and target energy. The Air Force is currently in advanced testing for the Active Denial System (ADS), intended to deter and deny individuals from entering an area. The emitted beam can produce mild burning sensations on the skin from up to 700 yards, without causing fatal or permanent effects on people[90]. The Marine Corps is interested in producing a system mounted on the Humvee, or (with improvements in size and weight) on a UAV, but the system is unlikely to be deployed within the next five years[91]. ADS could provide an alternative to kinetic non-lethal crowd control munitions, to deter individuals from an area such as a main road intersection. In the past, denial has often meant destruction of such throughways (e.g. destroying bridges, blocking harbours). With an effective nonlethal denial system, such infrastructure may be left intact for friendly use, thereby alleviating the pressure on engineering and logistics corps, and reducing the overall level of wartime destruction. Moreover, the long range of ADS makes it most suitable against armed mobs, whose accurate range of fire would be less than the ADS.

### High Powered Microwave

High powered microwaves (HPMs) cause disruption to electronic systems and engines, including vehicles, computers and communications[92]. Tactically, this could be used to stop a car that has run through a checkpoint without risking the lives of the passengers[93], or blind and deafen an enemy's defences. However, HPMs have important strategic uses in battlefield preparation. CENTCOM is reported to have received munitions fitted with HPM

[89] E. R. Bedard, "Nonlethal Capabilities: Realizing the Opportunities", *Defense Horizons*, No. 9 (March 2002).
[90] United States Air Force, *Active Denial Technology Fact Sheet* (Kirtland, NM: Air Force Research Laboratory, March 2001), http://www.de.afrl.af.mil/Factsheets/ActiveDenial.html, accessed 7th March 2003.
[91] GlobalSecurity.org, "Vehicle Mounted Active Denial System (V-MADS)", http://www.globalsecurity.org/military/systems/ground/v-mads.htm, accessed 7th March 2003.
[92] Janet Morris and Chris Morris, "Nonlethality and Homeworld Defence: Containing Barbarism – Nonlethality in the 21st Century", *World Defence Systems*, Vol. 4 No. 1 (April 2002), pp. 110-115: p. 111.
[93] One such incident occurred in Somalia, where US Marines shot a killed the civilian occupants of a car that had run through a UN checkpoint.

antennae to use in the opening stages of a war against Iraq[94]. If made available in infantry systems, HPMs could disable the power in a building in preparation for a surprise night raid.

### Pulsed Energy Projectile

Again employing electromagnetic energy to incapacitate an individual, the Pulsed Energy Projectile (PEP) is frequently described as being analogous to stun-phasers seen in science fiction serials. The directed energy creates a flash-bang effect at the target that produces a pressure pulse, causing reversible disabling effects from disorientation to temporary paralysis at 10-500 metres. According to Col. George Fenton, director of the JNLWD, a vehicle-mounted system is "less than ten years from fielding"[95]. This would go a step beyond the ADS, from deterrence to incapacitation, which would allow for easier arrest of individuals.

### Acoustics

In addition to electromagnetic energy, advances have been made in the accuracy of acoustic weapons. Acoustic weapons have a recent history of field use, with the British Army deploying an ultrasonic riot control weapons in Northern Ireland[96], and US forces reportedly using uncomfortably loud rock music to oust Manuel Noriega from the Vatican Embassy in Panama[97]. Acoustic weapons, using ultrasonic or infrasonic wavelengths, can cause blunt object trauma, nausea and disorientation. The US Army has developed the directed stick radiator (DSR) acoustic weapon[98]. Emitting audible sound of high intensity so as to cause pain and disorientation, the DSR can be clipped to an M-16. With a range of 15 feet, the DSR would be unsuitable for crowd control, but could be used to clear rooms or disorient individuals[99]. However, effects were not found to be neurologically universal, meaning that capitulation would be dependent on the degree of motivation, and it was subsequently dropped by the JNLWD[100]. Against larger crowds, many acoustic weapons are less effective, although the Department of Energy is pursuing a gaseous ionisation project that produces thermal-acoustic waves over very large areas. If perfected, this technology

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[94] "Fighting a 'Smart' War", *Newsweek International*, 17th February 2003, p. 29; see also Jim Krane, *New Weapons Ready to Fight Iraq*, Associated Press, 16th February 2003.
[95] Harold Kennedy, "U.S. Troops Find New Uses for Non-Lethal Weaponry", *National Defense Magazine* (March 2002), pp. 26-7.
[96] Robert Rodwell, "Squawk Box Technology", *New Scientist*, Vol. 59 No. 864, 20th September 1973, pp. 667-668.
[97] Jurgen Altmann, "Acoustic Weapons – A Prospective Assessment", *Science and Global Security*, Vol. 9, 2001, pp. 165-234: p. 171. Also, Barbara Starr, "Non-lethal Weapon Puzzle for US Army", *International Defense Review*, Vol. 26 No. 4, 1993, pp. 319-320: p. 320.
[98] Roxanna Tiron, "Acoustic Energy Research Hits a Sour Note", *National Defense Magazine*, (March 2002), p. 29.
[99] Morris and Morris, op. cit., p. 112.
[100] Roxanna Tiron, "Acoustic Energy Research Hits a Sour Note", op. cit.

would be incorporated in PSYOPS, where civilian radio broadcasts are currently used, to speak to entire city populations from the sky[101].

### Blue-on-Blue Blunders

The introduction of non-lethal weaponry to the battlespace would also greatly reduce the likelihood of fratricide. While instances of friendly fire may not significantly decrease with many systems, deaths arising from such instances will. One only has to look at the statistics of the 1991 Gulf War where, albeit under non-urban conditions, coalition deaths from friendly fire greatly outnumbered Iraqi inflicted fatalities[102].

Infantry are equipped with ammunition that is designed to be lethal and accurate at ranges far in excess of those normally encountered in the confined MOUT setting. As such, unintended casualties can often occur as a result of unpredictable impact behaviours of the rounds. In particular, Rangers in Mogadishu noted the dangers of friendly bullets penetrating the crudely made walls of houses, and of ricochets from corrugated iron or other barriers[103]. The DoE is currently exploring the production of powdered metallurgy and 'frangible bullets' at Oak Ridge National Laboratory[104]. Rounds of compressed metal powder will disintegrate on impact with hard targets, but are still capable of penetrating a human body, while achieving greater accuracy than standard rounds.

### The Barriers and Dangers of Non-Lethality

The history of warfare as a savage and total endeavour forms the basis of many of today's international conventions and norms. Article 36 of the Additional Protocol to the Geneva Conventions, for example, obliges states to ensure that all new weapons do not infringe international humanitarian law[105]. The Chemical Weapons Convention prohibits military use of the pepper spray routinely used by domestic law enforcement agencies around the world. In addition to specific contradiction of international treaties such as the Blinding Laser Ban, Ottowa Treaty and Conventional Weapons Convention, NLWs may contravene more generalised principles of conflict such as the prohibition of superfluous injury, prevention of unnecessary suffering and distinction of civilians from military

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[101] http://www.llnl.gov/adiv/projects/dfroula/art.html, accessed 20th March 2003.
[102] In this example, the non-urban battlespace allowed the use of stand-off platforms which, while more precise, lacked the intimate on-the-ground knowledge. Nevertheless, infantry engagements in MOUT can be expected to yield extremely high instances of fratricide, notwithstanding the introduction of significant infantry intelligence capabilities (see previous section).
[103] See Bowden, op. cit.
[104] U.S. Department of Energy, "Non-Toxic Frangible Ammunition", Oak Ridge National Laboratory, http://www.ornl.gov/spm/methods/powder/NTammo/Ntammo.htm, accessed 7th March 2003.
[105] *Protocol Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts (Protocol I)*, 8 June 1977, Article 36.

targets[106]. While these conventions were undoubtedly laid down with good intent, they currently prevent and restrict the use of less lethal force in conflict[107].

Not all NLWs are the panacea that they appear. After exciting promises of the potential for 'rigid foam' to seal throughways in buildings, the JNLWD found that it just did not compare in effectiveness and efficiency to a nail-gun[108]. Furthermore, many NLWs can be entirely lethal if used incorrectly. Many DEWs, for example, are currently only non-lethal at their targeted range, and could easily kill an individual that happened to walk into the beam. The DoD's laser dazzling programmes of the 1990s, were stopped prematurely due to permanent injuries[109]. DEWs also suffer from line-of-sight difficulties – a perennial problem for MOUT forces. Furthermore, more practical issues arise in tactical settings. Battle damage assessments (BDA) will be less reliable after NLW use. The effects of non-lethality are far subtler and less permanent than lethal force, therefore possibly obscuring BDA accuracy or necessitating numerous or regular re-strikes to achieve the military objectives of lethal force[110]. Additionally, there are the 'hard-soft' lethality links: while the DSR may incapacitate an individual without causing harm, if that person happens to be operating a vehicle, death can still result. An HPM that destroys the power service could lead to flooding and disease as water systems cease operation, as happened in Baghdad in 1991. Such is the sophistication of invisible bullets like the PEP that its use could provoke bouts of hysteria in a primitive mob witnessing its effects, potentially making their behaviour more volatile.

Finally, NLWs may set inappropriate precedents for their use. Such is the political appeal of non-lethal weaponry that commanders may be encouraged to use them when lethal force is more appropriate[111]. In this context, non-lethal weapons should not be considered as equal to, or substitutions for, lethal weaponry. Furthermore, this situation will lead to a 'lethality trap' for the armed forces. When the public become accustomed to clinical, bloodless battles fought with NLWs, media attention to the few applications of lethal force

[106] Joint Forces Quarterly, Spring 1999, p. 90
[107] For a greater discussion of the legal implications of non-lethal weapons, see *inter alia* Narang, Harris and de Swarte, op. cit.; Vincent Sautenet, "Legal Issues Concerning Military Use of Non-Lethal Weapons", *Murdoch University Journal of Law*, Vol. 7 No. 2, June 2000; David Fidler, "Non-Lethal Weapons and International Law: Three Perspectives on the Future", *Medicine, Conflict & Survival,* Vol. 17 No. 3, 2001, and other articles in this volume.
[108] Harold Kennedy, "U.S. Troops Find New Uses for Non-Lethal Weaponry", op. cit.
[109] GlobalSecurity.org, "Vehicle Mounted Active Denial System (V-MADS)", op. cit.
[110] Martin Hubbard, "Non-Lethal Capabilities and the Road Ahead", *World Defence Systems,* Vol. 4 No. 1 (April 2002), pp. 105-107: p. 107.
[111] Malcolm H. Weiner, *Non-Lethal Technologies, Military Options and Implications; Report of an Independent Task Force*, Council on Foreign Relations, 1995, p. 8.
http://www.cfr.org/p/resource.cgi?pub!3326, accessed 20th February 2000.

will be highly magnified, leading to second-guessing the decision to use such force[112]. Removing lethality from war fundamentally alters the perception of war as a destructive phenomenon. Non-lethal warfare may not be seen as war at all, possibly justifying increased 'conflict' and intervention, complicating all precedents of the essence of war and further confusing the nature of 'military affairs'.

[112] D. B. Hall, *Rules of Engagement and Non-Lethal Weapons: A Deadly Combination?* (Quantico, VA: USMC Command and Staff College, 1997).

# PART THREE: Achieving a Revolution in Urban Military Affairs: Non-Technological Innovation and Conclusions

# Structural Adjustments

The technologies noted in the preceding section will only bring about improvements in MOUT when accompanied by changes in doctrine, training, tactics, procurement and strategic thinking. Technology is only the first step toward implementing an RMA, and therefore pronouncements on the revolutionary effect of technology must be tempered by the non-technological hurdles that must also be overcome.

## Research, Development and Acquisition

Many of these technologies are originating in and being driven by the commercial and scientific sectors. By necessity, these industries thrive on innovation and entrepreneurialism, where, by contrast, conservatism prevails in military structures. The symbiotic military-industrial relationship has traditionally followed a needs-based approach to technological innovation, whereby mission commanders would state their needs and request the scientific community to deliver. The future RMA necessitates a technology-based approach to R&D. Technologies must be free to develop their potential and then tested for military potential. In the words of one General, "we ought to just step back, relax and be prepared to exploit it"[113].

The age of the military-industrial complex is in decline; no longer will innovation and R&D be the sole domain of the state. There is now more commercial R&D activity than the combined defence budgets of the G7 countries[114]. The sheer pace of technological change is challenging the military's ability to adapt, and accept that tried and tested models are not longer viable. Parochial military institutions may "simply fail to grasp the significance of radically new technologies because they are by definition difficult or impossible to assess based on existing paradigms and concepts of operations"[115]. Moreover, a military that is already tightly stretched to maintain a global presence and military advance via continued dependence on existing systems is poorly positioned to achieve the exponential jump in capabilities that the new concepts promise[116]. The commercial sector is well placed to make

[113] Major General Robert Scales, United States Army. Remarks made at a National Defense Industrial Association conference, June 2000. Courtesy of the US Army War College Public Affairs Office, Carlisle Barracks, PA, June 2000, cited in Thomas K. Adams, op. cit.
[114] Howard J. Marsh, "Emerging Technologies and Military Affairs", in Thierry Gongora and Harald von Riekhoff, *Toward a Revolution in Military Affairs? Defense and Security at the Dawn of the Twenty-First Century* (London: Greenwood Press, 2000), pp. 61-75: p. 70.
[115] O'Hanlon, "Beware the RMA'nia", op. cit.
[116] Christopher Gunther, "You Call This a Revolution?", *Foreign Service Journal*, September 1998.

economies of scale, share expertise and achieve more cost-effective results than the often inefficient spending of the defence establishment. For example, in upgrades to the 4th Infantry Division vehicles, a reportedly reinforced commercial computer costing $20,000 performed better than a $100,000 military specifications model[117].

However there are several problems associated with a commercial-based approach to R&D. There is the obvious advantage in maintaining a significant military research capability, to retain some control of the commercial proliferation of sensitive technologies. Furthermore the dislocation of research from the military means that fundamental economies-of-scale and -access cannot be made. For example, researchers at Georgia Tech University are working on tuning Sandia's microchip laboratory to detect traces of anthrax. While anthrax anti-bodies can be purchased commercially, they must be tested against anthrax spores, which are closely controlled. Work is delayed and impeded by having to send their tests away to secure laboratories[118].

### Doctrine

Urban warfare lessons have been well learned throughout human history, not just in the twentieth century. Indeed, accounts from antiquity tell of the horrific battles for Troy and Carthage, and almost 2500 years ago, Sun Tzu warned that "the worst strategy is to attack walled cities"[119]. However, current warfighting doctrine has not placed sufficient emphasis on MOUT and therefore infantry units remain unchanged from the outdated Cold War paradigm. In 1976, US Army's principal Field Manual dealing with urban combat (FM 90-10) stated that

> Commanders should avoid committing forces to the attack of an urban area unless the mission absolutely requires doing so.[120]

By 1993, a subsidiary to FM 90-10 had updated this dictum to the inevitability of urban intervention:

> The accelerated growth of cities have made the problems of combat in built up areas an urgent requirement for the US Army. This type of combat cannot be avoided.[121]

[117] O'Hanlon, *Technological Change*, op. cit., p. 53 note 85.
[118] Roxana Tiron, "Breakthroughs Sought in Chem-Bio Sensors", *National Defense Magazine*, (March 2002).
[119] Lionel Giles, *Sun Tzu's The Art of War* (London: Allandale Online Publishing, 2000), p. 8.
[120] U.S. Army Field Manual FM 90-10, 1976.
[121] U.S. Army Field Manual FM 90-10-1, 1993.

However, other than describing the exceptionality of urban combat, current doctrinal manuals give little or no guidelines for tactical operations under specific circumstances likely to be encountered (Table 4).

| Doctrinal Issue | FM 90-10 | FM 90-10-1 | MCWP 3-35.3 |
|---|---|---|---|
| Combined arms | POOR | FAIR | GOOD |
| Weapons effects | POOR | FAIR | GOOD |
| Non-combatant considerations | POOR | FAIR | FAIR |
| Special forces considerations | POOR | FAIR | FAIR |
| Third World Structures | POOR | POOR | FAIR |
| Joint Operations | POOR | POOR | FAIR |
| Multinational | POOR | POOR | POOR |
| Non-combat operations | POOR | POOR | POOR |
| Operational level MOUT | POOR | POOR | POOR |
| Tasks other than secure entire city | POOR | POOR | POOR |

POOR = Little or no mention of topic
FAIR = Some mention of topic with brief, but inadequate, discussion
GOOD = Considerable discussion, adequate or nearly adequate (RAND/Arroyo Center)

**Table 4: Scope of Current MOUT Doctrinal Manuals**[122]

For forty years NATO prepared to face numerically superior Warsaw Pact forces, with large divisions of armoured units in relatively open battlefields, using aerial support and precision long-range artillery forces, and with little political risk of 'overkill' or collateral damage. Today's force postures have changed little, yet the military affairs have changed greatly. When posture (i.e. the preparedness to meet military affairs), coincides with the current military affairs, and is implemented through sufficient force strength (numbers, firepower, etc.), then an RMA may occur (Figure 5).

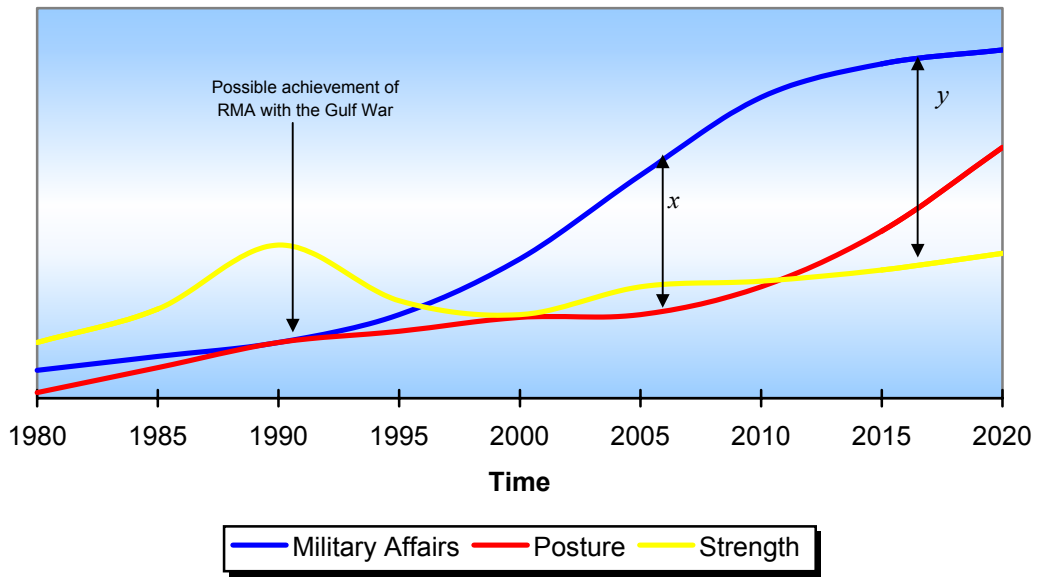


**Figure 5: Force Posture and Strength Trends in Relation to Military Affairs 1980-2020**[123]

[122] From Russell W. Glenn, *Marching Under Darkening Skies: The American Military and the Impending Urban Operations Threat* (Santa Monica, CA: Rand Corporation, 1998), p. 9.
[123] Hypothesised predictions based on author's estimations of trends.

This lingering Cold War paradigm greatly impairs the effectiveness of modern operations in which such conditions and formations have little relevance. Figure 5 shows how failure to maintain force posture and strength relevant to military affairs can produce a capabilities gap (*x*) and a vulnerabilities gap (*y*). The convergence of posture and military affairs would indicate the achievement of an RMA in 1991, while military strength determines the degree to which the RMA can be used. Typically, force posture will follow military affairs once the paradigm has been realised and the military oriented to it, while strength will follow afterwards as training, testing and procurement take time.

Tomorrow's doctrine will be led by technology. Abandoning the needs-based approach to innovation will allow technology to shape and influence doctrine in a way not seen before. With the symmetric advantage of the United States secured for the foreseeable future, the primary factor shaping doctrine and tactics will evolve from national security necessity to technological capability.

> The luxury of doctrine-led armies, for the most part, is at an end. The practice of deriving doctrine, then producing equipment to execute that doctrine, requires a clear threat to sovereignty and much national will. Many of the Cold War era equipments are a product of the doctrine-first philosophy[124].

Where current doctrine does address urban operations, they are treated as essentially a series of isolated small-scale operations designed to achieve relatively straightforward objectives such as raids. Little doctrinal attention is given to the conduct of joint or multilateral engagements in urban terrain or to policing operations[125]. This would appear to be wholly inimical to the concept of the 'three-block-war' in which forces will be required to conduct simultaneous missions of various intensity and with other agencies within a small urban area. The exceptionality of MOUT is not sufficiently recognised in current doctrine, a notion that has permeated concept development, training, and acquisition:

> This combination of common and unique battlefield needs means we must aggressively assess whether the common systems currently under development can be employed "as is" or require modification. Few systems include urban operations within their requirements statements, so they will likely fail the test. In many cases, the Army must be prepared to develop and purchase urban-specific systems that will enable forces to successfully conduct high-speed distributed urban operations against a competent foe.[126]

After sufficient recognition of doctrinal deficiencies must follow a new approach to training techniques. Most urban training centres are currently extremely small, usually replicating a European-style village, with few, if any, multi-storey structures. Realistic

[124] Marsh, op. cit., p. 70.
[125] Robert F. Hahn, and Bonnie Jezior, "Urban Warfare and the Urban Warfighter of 2025", *Parameters*, Summer 1999, pp. 74-86.
[126] Ibid.

conditions of many differing types of city should be recreated at such training grounds, including crude shantytowns and modern structures. The Marine Corps' Project Metropolis is a step in the right direction, encompassing urban training environment and unit structural innovations[127]. The establishment of urban training facilities abroad, would make use of local architectural styles and building materials to create realism.

Finally, strategic culture should begin to place greater emphasis on an understanding of urban populations. While special operations forces are routinely trained in cultural specialisation, these should be expanded to other brigades. It is widely recognised that failures in Somalia were due to a misapprehension of the dynamics of clan warfare. Human intelligence plays a greater role in MOUT than in other operations. This poses special challenges, however, not the least of which is the time needed to establish a viable network[128]. However, until sufficient technological breakthroughs are made to surpass human intelligence, concentration should focus on gaining a close appreciation of populations.

[127] Robert K. Ackerman, "Training is Key to Urban Warfare", *Signal Magazine*, (May 2001).
[128] Glenn, Steeb and Matsumura, op. cit., p. 16.

# Urban Operations Outlook

Urban operations represent a black hole in the current RMA pantheon of technological advantage. The technologies of precision intelligence and strike capabilities that afforded the US military so decisive an advantage in *Desert Storm* have few applications in the future urban war. With MOUT likely to become more prevalent in future, this absence of dominance in so crucial a capability, places the generalised RMA hypothesis on a somewhat dubious grounding.

## Communicating in Cities

Communications are likely to improve only incrementally. Interoperability will increase as communications are standardised across the forces and digitisation will allow for far greater amounts of information to be transmitted. Increasing miniaturization will allow hi-tech devices currently used by vehicles, ships and aircraft to be carried by the infantry, but these will be subject to power supply limitations. UAVs will provide battlefield relays in the short-term, until sufficient progress is made in the establishment of survivable and adaptive P2P networks.

Increasing bandwidth is enabling greater amounts of data, including video, to be received. However, while this may appear to be beneficial, we must again bear in mind the unique situation of the urban soldier. Soldiers demand knowledge not information. Infantry will have neither the time nor training to interpret millions of kilobits of raw data into useful and actionable knowledge. Therefore, while bandwidth increases are welcome, these advantages will not be appreciated without a better organic computational capability. Moreover, the introduction of heads-up-displays for the infantry will be a significant improvement in situational awareness, by simply applying technology used by the Air Force for decades to the infantry. These displays would also help eliminate some of the complications of infantry IFF technology.

Fundamental physical laws prevent the emergence of a revolutionary technology in the communications field. Radar and lidar will continue to be obscured by clouds and solid obstructions. The increasing sophistication of software will help to reduce interference and increase security in communications, while also fundamentally changing the nature of technological upgrades and maintenance. While GPS integration increases navigational accuracy, satellite systems will, in time, become vulnerable to inexpensive anti-satellite

weaponry[129]. The most revolutionary change in infantry communications lies in the proper implementation of networked command and control architecture, reducing communications to short-distance transmission and increasing survivability by incorporating multiple nodes. The Marine Corps' Project Albert represents a step towards network-centric warfare and the introduction of complex adaptive systems. Correct implementation of adaptive networks and sensor fusion would provide the building blocks for a battleswarm doctrine of the future.

### Extending Sensorial Range and Depth

Sensors, like communications, will improve marginally and will be the biggest encumbrance in improving the infantry's inventory. Sensor perception will continue to improve along existing trends, and significant progress will be made in the detection of chemical and biological agents. However these detection methods will continue to rely on physical contact with the substance, and as such will not be able to detect such agents before they are immediately present. Advances in acoustic-seismic sensors could allow for the detection of substances inside solid containers in the next ten years[130]. However these sensors will still have to be placed immediately adjacent to the target container, and will not, for example, be able to scan a building for chemical traces. Furthermore, active sensors will remain detectable themselves, while the art of crude visual deception will continue to frustrate remote target identification.

Notwithstanding the pace of sensor technology, significant improvements can be made in the application of robotics to these sensors. Infantry will be able to extend their sensorial range through deployment of unmanned ground and aerial vehicles. Additionally, increased automation will potentially free infantry from repetitive or static duties such as patrolling and surveillance[131]. Again, increased miniaturization and power management will expedite these technologies. However, the 'system-of-systems' nature of the RMA means that improvements in all of these technologies will be of negligible value unless accompanied by progress in their related systems. While the infantry's range will increase, the modest pace of sensor technology will limit the depth of sensorial ability.

### Non-Lethal Weapons: Panacea or Paper Tiger?

The military affairs of the future will be characterised by missions whose intensity can vary wildly and rapidly, where the US must co-operate with less technically capable forces, often to achieve non-military objectives. As such, the military must possess sufficient

[129] Adams, op. cit., p. 11.
[130] O'Hanlon, *Technological Change*, op. cit.
[131] Gulliver, *By the Edge of the Sword,* op. cit.

flexibility and tactical options to meet these demands. Future battles will be increasingly characterised by the proximity of non-combatants, and successes defined by political terms and casualty limitation. Enormous potential exists in the application of non-lethal force options for tomorrow's infantry forces. While the electromagnetic spectrum may hold promise, many developmental DEWs are unsuited to large area use and can be lethal if incorrectly targeted. However, equally important capabilities can be provided through the correct application of existing non-lethal means. Improvements in this area will not be determined so much by technology, but by necessary structural and institutional changes. In particular, concerted efforts must be made to secure re-negotiation of many existing international treatises to allow legal application of non-lethal force. This is likely to be an extremely time-consuming and bureaucratic struggle. However, while non-lethal force can be applied unlawfully, legality and legitimacy will ensure that it does not acquire a stigma that could potentially jeopardise its effectiveness, and politically discourage its application. Moreover, NLWs will require acceptance into strategic culture within the military, in order that it receives equal consideration as a force option alongside conventional means. Parochial militaries are slow to change tried and tested tactics, and feel less political pressure for casualty efficiency than policymakers.

| | Effect on MOUT | Obstacles |
|---|---|---|
| **Communications** | Low | Portability, power |
| **Sensors** | Low-Moderate if widespread | Physical obstructions |
| **Robots** | Moderate | Costs |
| **Non-lethals** | High | Institutional, legal |
| **Networks** | High | Interoperability, only a means (dependent on sensors etc). |

**Table 5: Summary of Probable MOUT Innovations**[132]

## Prospects for the Future of Urban Operations

The technologies traditionally ascribed to the current RMA phenomenon will have negligible impact on MOUT. Nevertheless, a general shift in strategic thinking toward preparing for urban battles in which the US will largely be symmetrically opposed will force the better application of existing and emerging technologies into urban forces. Therefore, we could potentially witness a revolution in urban military affairs in the near-future, through a tailored approach to urban mission requirements. The greatest potential for this revolution lies in the increasing situational awareness of the infantry, made possible through extending the range and depth of urban sensors, and the means by which data is communicated. Tasks traditionally reserved for the foot-soldier will be passed on to machines, while soldiers gain increased autonomy from their commanders through enhanced situational awareness. A

[132] Author's estimations based on the findings of this report.

similar and concurrent political revolution could be achieved through the proper allocation of non-lethal technologies, allowing forces to apply varying degrees of force, thereby reducing casualties and increasing political propensity to deploy. Nevertheless, a gulf will continue to exist between the effectiveness of forces in open and in urban battles, where the fog of war will remain densest. In some ways, the increasing prevalence of MOUT in the future of military affairs is welcome, as it will undoubtedly add impetus to its study, and boost the pace of innovation. Potential to revolutionise urban military affairs exists, but it may prove to be a painful route in getting there.

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