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The Revolution in Military Affairs, its Driving Forces, Elements and Complexity

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- Grundlagen, Möglichkeiten und Formen von Rüstungskontrolle, Abrüstung und Nonproliferation nach dem Ende des Ost-West-Konflikts sowie die Entwicklung von anwendungsbezogenen Konzepten präventiver Rüstungskontrolle

- „Monitoring" der fortschreitenden Rüstungsdynamik und Rüstungskontrollpolitik in Europa und weltweit mit Fokus auf moderne Technologien

- Technische Möglichkeiten existierender und zukünftiger (Waffen-) Entwicklungen, besonders im Bereich Raketenabwehr und Weltraumbewaffnung

Der steigenden Komplexität solcher Fragestellungen wird in Form einer interdisziplinär arbeitenden Forschungsgruppe Rechnung getragen. Die Arbeitsweise zeichnet sich durch die Kombination von natur- und sozialwissenschaftlichen Methoden und Expertisen aus. Durch die intensiven Kooperationen mit anderen Institutionen unterschiedlicher Disziplinen wird insbesondere Grundlagenforschung im Bereich der naturwissenschaftlich-technischen Dimension von Rüstungskontrolle geleistet. Darüber hinaus beteiligt sich IFAR auch an einer Reihe von Expertennetzwerken, die Expertisen aus Forschung und Praxis zusammenführen und Forschungsanstrengungen bündeln.

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Die Arbeitsgruppe kooperiert mit einer Vielzahl von nationalen und internationalen Organisationen.

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The Revolution in Military Affairs, its Driving Forces, Elements and Complexity[*]

Introduction

The current concept of a "Revolution in Military Affairs" mainly characterizes the transformation of the US military to smaller, more powerful forces. It is driven by structural changes in the international system, the high investment in R&D and military expenditures by the US government, the dramatic advancements in Information and Communication Technologies and the integration of these military, doctrinal, and technological factors into new military structures and tactics. This current revolution in *American affairs* has been a capital-intensive evolution, and while these innovations have lead to tactical victories over opposing forces on the battlefield, it is not yet clear that they have contributed to stability in the larger strategic context. Indeed, even the tactical advantages are eroding as potential opponents retool their own military doctrines. The strategic response runs the length of technological spectrum, from the development of countermeasures such as in the proliferation of WMD to the development of low-tech warfare strategies and tactics like IEDs detonated by cell phone. The proliferation of conventional weapons combined with the adaptation of new asymmetric tactics is another consequence. Precision weapons are minimizing the casualties of the RMA forces, but not necessarily the casualties of the adversary. The Iraqi war demonstrates that the fog of war is not overcome and wars fought with Precision Guided Munitions are not necessarily "clean". In consideration of these facts the efforts must be intensified to develop new methods for effective arms control.
Overall the key task for the globalized world is first and foremost to develop strategies to win the "hearts and minds" of people in zones of violent conflict. The inclusion of the civil society is a basic element and armed forces should seek the dialogue with the civil society before it comes to war.

1. Science, Technology and the Military

Science and technology are dominant factors in modern society. The application of science is fascinating and can be highly beneficial to humanity, but it has also led to the development of the means to destroy human civilization. Science, which was developed on humanistic foundations and justified in terms of the betterment of mankind, contributed significantly to the pursuit of military purposes during the 20th century. The industrial and scientific revolutions of the 19th and 20th centuries also politicized science, culminating most visibly in World War II with projects such as missiles, nuclear weapons, radar, operations research and cryptography. In the 20th century, three important science-based innovations led to significant technological progress, but also to new military options: (1) nuclear weapons, (2) biotechnology and (3) information and communication technologies (ICT). Science, Engineering and Technology (SET) is used to modernize and build up weapons arsenals, as well as to influence military strategy via the adoption of military and civilian research results (Add-On Paradigm). The distinction between military and non-military activities is becoming more and more blurred**.** Especially in the USA, but also in the UK, the military sector has "a very *large* and *disproportionate effect"* on SET. A newly published study from Scientists for Global Responsibility examined the influence of the military in the governance and direction of SET in the UK and concluded that the military sector is a *major player* in the commercial

[*] *This Report is an updated and extended version of an article with the same title which was written in 2006 for the Physics Journal Complexity No. 50, pages 50-61, published in 2008.*

partnerships in SET supported by the government.[1] The report's authors write that "military *support* of emerging technology such as nanotechnology is high (especially in the USA)". The next section explores the origins and driving forces of the current revolution.

2. Revolution in Military Affairs: Origins and Driving Forces

The concept of military revolutions goes back to the 1950s, but as Charles Townshend observed, "modern war" has to be seen as "the product of three distinct kinds of change: administrative, technological and ideological."[2] There have been several revolutions in military strategy throughout history, such as the innovation of the longbow in the 14th century; the introduction of gunpowder and artillery in the 15th; the Napoleonic *leveé en masse* – the first compulsory military service; the communications revolution brought by telegraphy; mechanization in the late 19th and early 20th century, which resulted in such technologies as tanks, aircraft and submarines; and, perhaps most importantly, nuclear weapons. Williamson Murray and McGregor Knox distinguish between military revolutions and revolution in military affairs.[3] In their view, military revolutions such as the "French Revolution" or the "advent of nuclear weapons" are cumulative and hard to predict in their consequences for modern states and societies. Revolutions in Military Affairs (RMAs), on the other hand, result in the defeat of enemies (e.g. in the 1991 Iraq war), but do not necessarily shape the character of states and societies.

The origins[4] of the current debate began in the 1970 and 1980s, when the Soviet Chief of Staff, Marshal Nikolai Ogarkov[5], and other Soviet analysts coined the term "military-technical revolution" to describe technical developments such as sensors, electronics, jet engines and precision munitions acting at stand-off range. The NATO and US "Follow-on Forces Attack" (FOFA) strategy intended to use "high-tech" strikes to counter the three-to-one numerical advantage of the Warsaw Pact armies in terms of main battle tanks, artillery and manpower. William J. Perry, then Undersecretary of Defense for Research and Engineering (1971-1981), introduced the "Offset strategy" to offset the Soviet advantages in numbers by Western technological superiority without maintaining a large standing army that would cripple "our own economy".[6] A new set of powerful military systems such as stealth fighters, global communications, and cruise missiles have been developed. Andrew Marshall, a leading proponent of RMA thinking, adopted Orgakov's arguments and started a debate on the coming military revolutions and possible answers by the US. He was particularly skeptical of the way traditional military thinking regarded large ships, aircraft and main battle tanks as the key pillars of armies fighting a prospective third world war. Starting in 1973, Marshall developed a small think tank, the Office of Net Assessment (ONA), within the DoD and nurtured many disciples who are now at the center of the Bush administration (including

1 S. Parkinson/P. Webber (eds): Soldiers in the Laboratory. Military Involvement in Science and Technology – and some alternatives by Chris Langley, January 2005.

2 C. Townshend: *The Oxford History of Modern War*, Oxford 2005, chapter 1, p. 3ff.

3 W. Murray, M. Knox (eds): *The Dynamics of Military Revolutions 1320-2050*, New York, 2001, chapter 1.

4 For the origins see: L. Freedman: *The Revolution in Strategic Affairs*, Adelphi Paper 318, Oxford 1998; B. Møller: *The Revolution in Military Affairs: Myth or Reality*, Peace Research Institute, Copenhagen, 2002 [http://www.copri.dk/copri/researchers/moeller/RMA.doc].

5 Orgakov's writings were meant as "a wake-up call" to draw attention to Soviet inferiority to the West in terms of computer technology, electronics and strike capability, see: G. Chapman: An Introduction to the Revolution in Military Affairs, in: *Changing Threats to Global Security: Peace or Turmoil*. Proceedings XV International Amaldi Conferences, Helsinki 2003, pp. 123-14.

6 W. Perry: '*The Revolution in Military Affairs: Peace or War in the 21st Century*', (Working Paper Nr.14, The Center for International Relations, University of California, Los Angeles 1997).

Donald Rumsfeld). Ultimately, the proponents of RMA dream of eliminating Clausewitz's "fog of war", i.e. removing unpredictability on the battlefield.

The starting point for public perceptions of RMA weaponry was Operation Desert Storm, the US-led war against Saddam Hussein's Iraq in 1991. This was the first time that many systems developed to cope with the armies of the Warsaw Pact were used under battlefield conditions. The use of GPS- or laser-guided weapons delivered by stealth fighters dominated the TV coverage and created the perception that the operation was a "surgical and clean war". Politicians and the military recognized the potential of this "new kind of warfare". The Iraqi side clearly came off worse, suffering an estimated 25,000 to 75,000 casualties.[7] Marshall commissioned a study by Andrew F. Krepinevitch, who drew the conclusion that the military revolution already existed at an operational level, but still required organizational and operational reforms. In 1993, Marshall also promoted the idea that new high-tech capabilities would lead to dominance on the conventional battlefield. The Joint Vision 2010 and 2020 documents, published in 1996 and 2000, aimed to describe how the US forces should expect to conduct warfare in the 21st century. They identified four technological trends: (1) long-range precision capability, combined with a wide range of delivery systems; (2) the ability to produce a broader range of weapon effects, from less lethal to hard-target kill; (3) low observable technologies and the ability to mask friendly forces; and (4) information systems and systems integration. The documents emphasize that high technology is only one dimension of warfighting. Military success also depends upon leadership, personnel, training, structures and operational concepts. Several schools of thought concerning the RMA can be identified today,[8] and the US military has widely accepted the "systems of systems" or "network-centric" approach.

Defense Transformation and the "Bush Doctrine"

The term "Revolution in Military Affairs" characterizes the current and ongoing transformation of US armed forces. With the Bush administration, the proponents of the RMA idea reached the centers of US military power and started to affect the US military.[9] Then a candidate for the presidency, in 1999, George W. Bush said that "[o]ur military is still organized for the Cold War threats, [rather] than for the challenges of a new century – for industrial age operations, rather than for information age battles".[10] Secretary of Defense Rumsfeld and his former Deputy Secretary, Paul Wolfowitz, have described themselves as "radical reformers" of the inert US military system and stressed the need for the "transformation of the US forces". The first full "top-down review" of the US military, the *Quadrennial Defense Review 2001* proposed only minor reductions in numbers and did not change the *status quo*. The attacks of September 11, 2001, interpreted as "acts of war", confirmed the view of top US decision makers that the threats of the 21st century were "asymmetric" and that US military structures have to be transformed in accordance with the new situation.[11]

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[7] M. Leitenberg: *Deaths in War and Conflicts Between 1945 and 2000*, Cornell University, Peace Studies Program Occasional Paper 29, 2003.[there is an updated version (3rd ed.) from 2006]

[8] M. O'Hanlon: *Technological Change and the Future of Warfare*, 2000 Washington D.C. , p. 11-17.

[9] A. Erger: Yoda and the Jedis: The Revolution in Military Affairs and the Transformation of War, in: *Bridges. The OST's Publication on Science & Technology Policy*, Vol. 7, September 20, 2005, [http://www.ostina.org/content/view/274/].

[10] G. W. Bush: A Period of Consequences, *The Citadel*, South Carolina, September 23, 1999, [http://www.fas.org/spp/starwars/program/news99/92399_defense.htm].

[11] See: M. Gordon and B. Trainor: *COBRA II. The Inside Story of the Invasion and Occupation of Iraq*, New York 2006.

The war in Afghanistan in 2001, which saw a combination of precision bombardment, battlefield surveillance by Unmanned Aerial Vehicles (UAV) and only Special Forces on the ground, was prosecuted successfully and seemed to confirm the success of the RMA paradigm. Also in 2001, Rumsfeld declared that "Network Centric Warfare" was the Pentagon's new organizational principle for military planning and the use of forces. [12] The "decapitation strike" launched on Baghdad on March 20, 2003 and the following massive air campaign and full-scale ground attack on Iraq lead to a stunning defeat of the Iraqi forces and a breakdown of Saddam Hussein's regime.

The basic idea of the "Bush doctrine" is to wage "preventive war" against terrorist organizations and rogue states. In his first state of the union address after the 9/11 attacks, President Bush stated that "time is not on our side. I will not wait on events, while dangers gather. I will not stand by, as peril draws closer and closer".[13] In his West Point speech, President Bush warned: "If we wait for threats to materialize, we will have waited too long". The National Strategy 2006 declares: "We are fighting a new enemy with global reach. The United States can no longer simply rely on deterrence to keep the terrorists at bay or defensive measures to thwart them at the last moment. The fight must be taken to the enemy, to keep them on the run."[14] Additionally, the idea that US technological capabilities make it possible to conduct warfare with a minimum of casualties and destruction is seen as central in the US public perception. President Bush outlined the essentials of this modern system of war in a speech to workers at a Boeing aircraft plant in April 2004: "By a combination of creative strategies and advanced technology, we are redefining war on our terms. … We've applied the new powers of technology... to strike an enemy force with speed and incredible precision. By a combination of creative strategies and advanced technologies, we are redefining war on our terms. In this new era of warfare, we can target a regime, not a nation."[15] The RMA idea, which the US Congress, the media and the public now tend to label "Defense transformation", is at the core of the security and defense policy of the current Bush administration.

Critics of the RMA argue that RMA technologies will proliferate, especially if they become cheaper. It is also argued that RMA technologies are particularly sensitive and thus vulnerable to counter-measures or direct attacks that take advantage of this. For instance, it is believed that well-trained cyber-soldiers are capable of penetrating or otherwise attacking electronic networks. Skeptics of the RMA paradigm argue that RMA might be better labeled an evolution rather than a revolution in military affairs. Many platforms, operational concepts and ideas that are now assigned to the RMA have been developed and tested since the 1970s and 1980s. We should also note that the RMA has so far manifested itself more or less entirely as a "Revolution in American Affairs". RMA is "capital-intensive, high-technology-prone and militarily decisive".[16] The term "Revolution in Military Affairs" is today a buzzword among strategists inside the US military elite, but in the research community "there is no consensus on whether the recent changes in military weaponry and strategy made possible by advances in information technology should be called a revolution."[17]

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[12] Department of Defense, *Network Centric Warfare*. Report to Congress, July 27, 2001, [http://www.Defenselink.mil/nii/NCW/].

[13] *The President's State of the Union Address*, Washington, January 29, 2002, URL [http://www.whitehouse.gov/news/releases/2002/01/20020129-11.html].

[14] *The National Security Strategy of the United Sates of America*, March 2006, [http://www.whitehouse.gov/nsc/nss/2006/print/sectionIII.html].

[15] *President Bush Outlines Progress in Operation Iraqi Freedom,* [http://www.whitehouse.gov/news/releases/2003/04/20030416-9.html].

[16] L. Freedman, The Third World War?, *Survival*, Vol. 43(4), Winter 2002-2003, pp. 61-88, p.61.

[17] Chapman 2003: 123-141 (see footnote 5).

The Driving Forces

Several political, economical and technical driving forces can be identified behind the current interest in RMA, especially in the United States:

1. Structural changes in the international system and a unipolar system of US military primacy in a new strategic environment;
2. High levels of investment in R&D and military expenditure, especially in the US;
3. Dramatic progress in ICT and other areas;
4. Integration of tactics, force structures and technological advances, training and simulation.

Ad. 1 – Structural Changes in the international system

The end of the East-West confrontation and the demise of the former Soviet Union brought a shift towards a more unipolar system with the US as the unchallenged sole global military superpower. Combined with major advances in science and technology, the main characteristics of US security policy are new military concepts and the will to use military power. Additionally, the offensive "preventive war doctrine" of the current Bush administration and the rhetoric that calls for "regime change" in rogue states has set aside the "last-resort principle" of previous US governments.[18] The US, which accounts for 46 percent of global military spending in 2006, has lowered the threshold on the use of military force, especially by means of the rhetoric of "regime-change" and the "war on terror" (Table 1).

Table 1: Top ten countries by military spending in 2006 in market exchange rate term (at constant 2005 US$)[19]

Rank	Country	Size $b	World Share, %
1	USA	528.7	46
2	UK	59.2	5
3	France	53.1	5
4	China	49.5	4
5	Japan	43.7	4
6	Germany	37.0	3
7	Russia	34.7	3
8	Italy	29.9	3
9	Saudi Arabia	29.0	3
10	India	23.9	2
Total		887	77

[18] Carl Conetta argues that the term "preventative war" is too generous because "it prescribes applying force even when reasonable people would conclude that conflict probabilities and adversary capabilities are modest or low." C. Conetta: Arms Control in the Age of Strategic and Military Revolution in: S. Albrecht, R. Braun, T. Held (eds): *Einstein weiterdenken. Thinking Beyond Einstein. Verantwortung des Wissenschaftlers und Frieden im 21. Jahrhundert. Scientific Responsibility in the 21st Century*, Frankfurt, 2006; pp. 243-272.

[19] Table: The fifteen major spenders in 2006, Information from the Stockholm International Peace Research Institute (SIPRI) 2007, [http://www.sipri.org/contents/milap/milex/mex_major_spenders.pdf]

Ad. 2 - High levels of investment in R&D and military expenditure and a strong scientific-industrial base

World military expenditure increased by around 22 percent in real terms over the five-year period 2002-2006, reaching $1158 billion constant (2005) US$ in 2006. This is only 3 percent lower than the 1988 peak of the Cold War military spending.[20] US military strategy is characterized by highly advanced military technologies and the infrastructures needed to use them. The US relies on a military, industrial and scientific network of government-owned arsenals, laboratories, industrial contractors and military institutions that stem from the Cold War.[21] According to Sapolsky *et al*.: "The driving force in the defense budget is not overseas threats but the need to sustain contractors with indispensable defense skills and technologies."[22] The core argument for this strategy is that the US always has to be one step ahead of its potential opponents to discourage them. There is a widespread belief that the United States' military-technological advantage means that no antagonist can oppose US forces with conventional weapons. Logically, future challenges would be "asymmetric", e.g. terrorism, sabotage, low-intensity conflicts, possibly involving the use of unconventional weapons such as biological or even nuclear weapons. After the 9/11 terrorist attacks, the Bush administration has accelerated this by focusing on a "capability based" development and procurement approach. Figure 2 shows the increase in the US Defense Budget in the last few years. For the 2009 fiscal year, the Bush administration has submitted a request to Congress for approximately 515.4 billion US Dollars.[23]

Compared to low-tech weapons such as small arms and light weapons, high-tech weaponry requires an industrial basis, is expensive to produce, difficult to use, has long R&D cycles, and is usually less prone to proliferation. It also requires the development of new strategies by means of training, exercises and the simulation of complicated procedures. Low-tech weaponry, on the other hand, is universally available, easy to use, and can proliferate rapidly.

Table 2: Characteristics of high-tech vs. low-tech weapons

"**high-tech**" vs.	"**low-tech**"
R&D, simulation and training complicated handling expensive production	easy handling universal availability
slow proliferation	fast proliferation
industrial basis required	sale (arms export)

Throughout history, the partition between civilian and military technologies has been permeable. Scientists were educated in civilian universities and technologies were produced by civilian contractors. Only in the industrial age did specialization increase, thus making separate military developments possible. During the Cold War, huge volumes of resources

[20] See: Table on world and regional military expenditure, 1988-2006, Information from the Stockholm International Peace Research Institute (SIPRI), 2007 [http://www.sipri.org/contents/milap/milex/mex_wnr_table.html]
[21] See: H. M. Sapolsky, E. Gholz, A. Kaufmann: Security Lessons from the Cold War, in: *Foreign Affairs*, Vol. 78(4), July/August 1999, pp. 77-89.
[22] Ibid. p. 88.
[23] See: DoD Fiscal Year 2009 Budget Request, Press Release, February 2008, [http://www.defenselink.mil/comptroller/defbudget/fy2009/2009_Budget_Rollout_Release.pdf]

were put into specialist military developments such as nuclear weapons and missiles. After the end of the Cold War, the Clinton administration introduced a policy of the increased use of civilian technologies for the military. The RMA utilizes advanced ICT from the civilian sector.[24] The "dual-use paradigm" is certainly at the heart of the current RMA.

The United States is spending more than half of its total R&D budget on the military. In 2006, the DoD increased its R&D budget by 4.1 billion US$ to 78.8 current (2007) billion US$. In the European Union, four countries (UK, France, Spain, Germany) accounted for 97 percent of military R&D spending: 8.9 billion euros (in 2003 values).[25] The defense-related proportion of 2006 total government R&D in the UK was 28.3 percent, in France it was 22.4 percent and in Germany, 6.4 percent.[26]

Ad. 3 - Dramatic Progress in Information and Communication Technologies (ICT)

One of the most important elements in the current RMA is the immense progress made in the area of ICT. Figure 3 shows the trend in processor speed for Personal Computers (PC) and Mainframe systems in MIPS (million instructions per second).Today a standard PC has the required calculating power to handle the data stream of an audio or video channel. In less than ten years, PCs will already be able to process data using optical fiber transmission. This is one example. Similar predictions could be made regarding for sensor developments, data storage and fusion, etc.

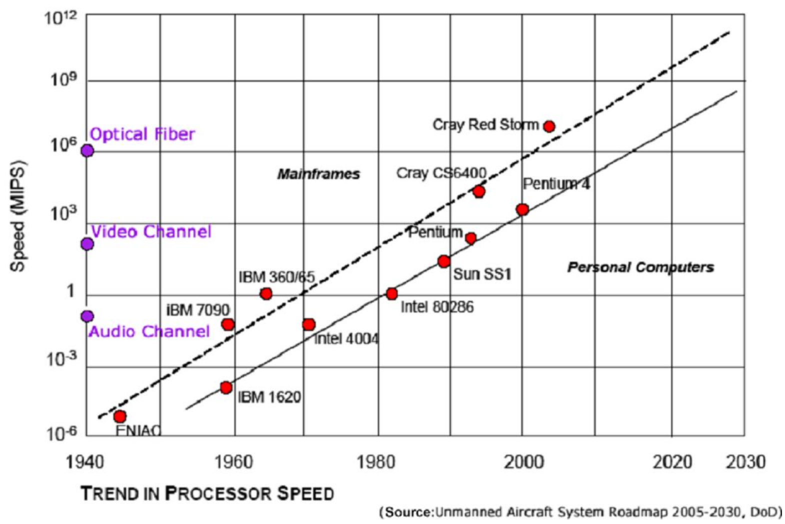

Figure 3: Trend in Processor Speed 1940-2030

The integration of recent advances in information, communication and surveillance technologies makes possible a wide range of new military technologies. The key to future developments is not so much a new wave of innovation in military technologies but the integration of diverse technologies in a "system of systems" and the permanent upgrading of this system via the constant modernization of its elements and connections. New sensors may be introduced, or the communication between these elements extended by a new generation of micro-processors that enable better and faster data exchange. The US military is particularly

[24] J. Reppy: A Dual-Use Technology in the New Strategic Environment, in: S. Albrecht, R. Braun, T. Held, pp. 243-272 (footnote 25); see also J. Reppy, Managing Dual-Use Technology in an Age of Uncertainty, *The Forum*, Vol. 4 No. 1, Article 2, 2006 [www.bepress.com/ forum/vol4/iss1/art2].

[25] Parkinson and Webber (eds), (see footnote 1).

[26] OECD, Main Science and Technology Indicators, October 2007

enthusiastic about the RMA, which it believes "…will give us dominant battlespace knowledge and the ability to take full military advantage of it."[27]

Ad. 4 - Integration of tactics, force structures and technological advancements: Net-Centric Warfare

The USA and its demand to organize its global military strategy more efficiently are currently driving military-technical developments towards: [28]

- Decentralization and flattening of hierarchies: the RMA removes the distinction between the strategic, tactical and operational levels by enabling the direct communication of orders and information to the units that require them.
- Precision strikes: the entire intelligence, surveillance and reconnaissance (ISR) loop supports the acquisition of targets and their attack by guided weapons.
- Increased maneuverability of units that can also be assembled and disassembled on an *ad hoc* basis and over longer distances.
- Information warfare operations, i.e. the use of information or its processing to coerce an opponent by manipulating or destroying its information infrastructure without directly engaging its military force.

It remains to be seen whether these military capabilities will really create the intended dominance on the battlefield in actual combat situations. However, in purely conceptual terms, the following are the key elements for the implementation of RMA:

- Global engagement / access
- Real-time intelligence
- Communication and target strategy
- Space Infrastructure
- Strong R&D basis including integration
- and the crosslinking of elements

The crosslinking of as many of these elements as possible is the key factor for the transformation of US forces and is currently referred to as net-centric warfare (NCW; see next section).[29]

3. The Main Elements of the Current Military Transformation

At the heart of the current RMA is the exploitation of the revolutionary advances of the information age. The computational power and storage abilities of computers have been increasing by a factor of ten every five years. The main elements of the information age are personal computers, fast global audio, video and data communication and the networking of many users. Laser and fiber optic communication, encryption technologies and data fusion allow rapid routing and processing of data. Additionally, automatic pattern recognition

[27] Gen. Ronald Fogleman, U.S. Air Force Chief of Staff cited after Thayer 2000: p. 44 (footnote 28)

[28] A. Thayer: The Political Effects of Information Warfare: Why New Military Capabilities Cause Old Political Dangers, in: *Security Studies* 1/2000.

[29] A key document on NCW is: Arthur K. Cebrowski/John J. Garstka: Netcentric Warfare: Its Origin and Future, in: *Proceedings of the US Naval Institute*, Vol. 124, January 1998. According to this source, the concept of NCW was inspired by practices in the NY police and US companies.

techniques, improved radar systems and infrared sensors (for night vision or weather independent surveillance) allow highly detailed imaging of geographical situations.

The main challenge for politics and the military is to implement the technological elements in a military and political concept. The current status of the RMA in the US military seems to be rather "nebulous and mutable", but some stable elements can be identified: [30]

- Command, Control, Computer, Communication, Intelligence (C4I)
- Intelligence, Surveillance, and Reconnaissance (ISR)
- Precision-guided munitions (PGM) with assorted ranges
- New weapon principles (laser, microwaves, non-lethal weapons [NLWs])
- New sensors and data fusion
- Stealth technologies
- Agile, lower-cost weapon platforms and delivery systems (UAVs, cruise missiles)
- Missile and air defense
- Stand-off weapons with higher protection
- Space-based warfare

Table 3: Overview of the elements, technologies and weapon systems:

Elements	***Technologies***	***Military System***
Revolutionary advances in computers and communication for better Intelligence, Surveillance and Reconnaissance(ISR)	Computer and network technologies, encryption, pattern recognition, communication	Command, Control, Communication, Computer, Intelligence, Tactical Internet
Jointness and data fusion	Sensors, Storage, Platforms, GPS, INS	Space Networks, JSTARS, AWACS, UAV
Precision munition and agile platforms	Special weapon effects, stealth technologies	JDAM, Cruise Missiles, UCAV, B-2, F-117, F-35 JSF, Laser-guided bombs
Smaller force structures	Digital Communication	Special Forces, UAVs, Soldier systems, NLW, Predator

The C-4I/ISR Revolution

Command, Control, Computer, Communication and Intelligence (C4I) networks are based on secure communication lines and rapid computer processing from rear command centers to forward command lines, including man-portable laptops or the tactical PC stations of fighting units. Many platforms, from satellites to UAVs or aircraft, can be used to distribute relevant information. The space-based Global Positioning System (GPS) constellation is used to determine the exact location of friendly or enemy troops. The US has a computerized "Battle Management System", which not only collects data on combat successes but also presents the field commanders with planning information.

A wide range of multi-spectral sensors make possible the creation of Intelligence, Surveillance, and Reconnaissance (ISR) networks. ISR acquisition can take many forms: Signals intelligence (SIGINT) or Communications Intelligence (COMINT) can identify all kinds of military communications as well as signals radiated by equipment. The ISR spectrum

[30] See Chapman 2003, p. 132 (footnote 5).

extends from satellite surveillance and reconnaissance (KH-11, Lacrosse etc.), UAVs (Global Hawk, Predator), to aircraft such as the Joint Surveillance and Target Attack Radar System (JSTARS) or AWACS, which serve as flying command and control centers for ground or air operations. Images of the target area such as air defense systems or front lines can be useful for soldiers, as can updated electronic maps of the terrain.

The information gathered by means of all these data-collection capabilities across so many platforms has to be compiled, processed and shared among the different service branches (navy, army and air force, etc.). Data fusion from all service elements is thus an important feature of NCW. "Joint-service commands" worked very successfully during the Iraq war 2003. A "network-centric" system of systems consists of an observation (ISR) system, a communication system, a system of data processing and analysis, a strike system to deliver munitions with pinpoint accuracy and an evaluation system to ascertain the effectiveness of such attacks.

Agile, lower-cost weapon platforms and delivery systems

Cruise Missiles (CM) and Unmanned Air Vehicles (UAV) are a new class of "air systems fitted with aerodynamic surfaces that provide lift to keep them airborne during the entire mission."[31]

Cruise Missiles

Cruise missiles (CMs) have air-breathing engines and can fly variable flight profiles at both low and high altitudes. They can be pre-programmed and perform precision-strike missions with high accuracy (circular error probable = 2-50m).With a modular payload between 200 and 500 kg, they can have a range of 150-3,000 km depending on launch platform (aircraft, ship, submarine or ground-based). CMs are inexpensive systems compared to ballistic missiles or aircraft with a low infrared and radar signature. Various in-flight guidance systems and their combination with inertial or satellite-based navigation, terrain-contour guidance and terminal homing systems give them pinpoint accuracy. If a state has aero-industrial capabilities, it can manufacture CMs. Lawrence Freedman called CM "the paradigmatic weapon of RMA"[32] and indeed the US used the Tomahawk CM, which was first deployed in 1984, extensively in Desert Storm (CMs fired: 332), Desert Fox (415) and Iraqi Freedom (955).

Countries with aircraft industries can afford to develop and build CMs for their own use or for export. There are three paths to acquiring a CM: (1) indigenous development, (2) the conversion of an anti-ship missile and (3) purchase from the growing ranks of manufacturers. It is believed that today 80,000 CMs, representing 75 different systems, are deployed in 81 countries, but 90 percent are older short-range systems (max. 100km) or anti-ship CMs (ASCMs). A study concluded that nearly 70 nations possess sea- and land-launched ASCMs and 20 possess air-launched CMs (ALCMs).[33] The ranks of manufacturers are expanding: 19 countries currently produce ASCMs and, of these, eleven export them.[34] Russia, certainly an important manufacturer of CMs, is jointly developing a 290 km ASCM with India. Only the

[31] See D. Gormley: New developments in unmanned air vehicles and land-attack cruise missiles in: *SIPRI Yearbook 2003: Armaments, Disarmament and International Security*, Oxford, 2003, chapter 12, pp. 409-432.
[32] L. Freedman: 1998, p.70 (footnote 4).
[33] T. Mahnken: *The Cruise Missile Challenge*, CSBA, Washington DC, March 2005.
[34] Ibid., p.13

US, Russia and probably China[35] have strategic CMs with ranges greater than 1,000 kilometers; Israel and India might follow. Around 42 new systems are in development in different countries. Air defense against such low-visible systems “over the horizon”, which have a small “radar cross section” and a small “thermal signature”, is possible but not easy and very cost-intensive.[36] Their technical capabilities, low thermal and radar signature, and low cost make them an attractive weapons system. There is also a growing concern that the proliferation of unmanned air vehicles (UAVs) can pose a threat to the US[37] and other countries.

Unmanned air vehicles

Unmanned air vehicles (UAVs) are reusable loitering systems primarily used today for ISR missions, but also for target acquisition, damage assessment and communication relay. The operators of such UAVs can sit 1,000 km away without risking their lives. These UAVs are paradigmatic for NCW. They are generally unarmed systems, but some have been modified to carry weapons. They can fly autonomously or be piloted remotely at high or low altitude and are equipped to return home. They can be very large and heavy or very small in size, can use a range of propulsion systems and can transport different payloads (from a few kg to 250 kg). The various systems range in cost from a few thousand to tens of millions of US dollars. Important characteristics are endurance time, weight, range, ceiling, etc. Different payloads can be used for a wide spectrum of missions beside traditional tasks such as meteorology, searching for WMD or combat search and rescue. UAVs and Cruise Missiles can also be used for the delivery of bioweapons. D. Gormley follows that “the spread of these systems globally will affect US military dominance, regional stability and homeland defence.”[38]

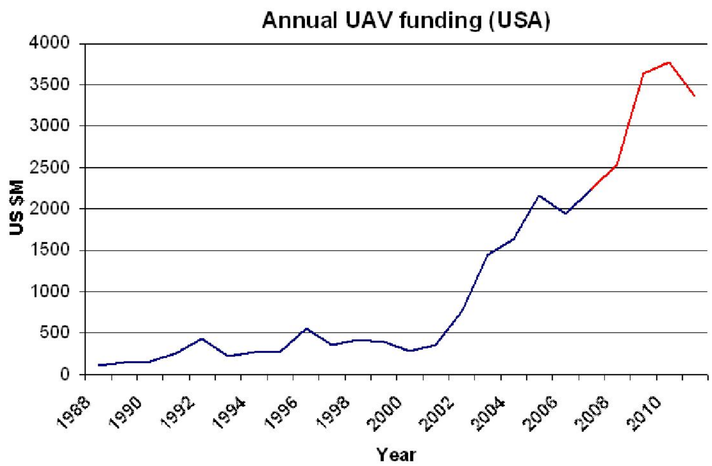

Figure 4: Increasing annual funding for UAVs[39,40]

The medium altitude long endurance (24 hours) MQ-1 Predator has flown since 1995 surveillance missions over Iraq, Bosnia, Kosovo and Afghanistan. The high altitude long-endurance RQ-4 Global Hawk is a very large aircraft with a payload of 1-2 tons of electronic and remote-monitoring equipment, including infrared, electro-optical and radar sensors. It operates at an altitude of 20 km with a constant speed of 500 km/h. Such UAVs can help to

[35] See: Land-Attack Cruise Missiles (LACM) Hong Niao / Chang Feng, GlobalSecurity.org [http://www.globalsecurity.org/wmd/world/china/lacm.htm]
[36] See: M. O’Hanlon: Cruise Control, in: *The National Interest*, Spring 2002, pp. 89-93.
[37] US Department of Defense: *Unmanned Aircraft Systems Roadmap 2005-2030*, Washington, D.C.
[38] See Gormley 2003, p. 432 (foonote 31).
[39] US Department of Defense: *UnmannedAircraft System Roadmap 2005-2030*, Washington, D.C
[40] US Department of Defense: *Unmanned Systems Roadmap 2007-2032*, Washington, D.C

track friendly forces and warn them of "what is behind the next corner". During the 2003 Iraq war, Global Hawk UAVs found 55 per cent of time-sensitive air-defense targets, while making up only three per cent of total ISR missions.[41] Hyperspectral sensor packages are under development that can analyze hundreds of frequency bands and might be capable of analyzing detailed information from the ground.

Miniaturized UAVs such as the "Over-the-Hill" Dragon Eye (1.8kg) and Pointer (3.6kg) can be hand-launched and operated by a single soldier at company or platoon level and have already been used in the 2003 Iraq war. DARPA and the US Army are exploring so-called Micro Air Vehicles (MAV), which have a wingspan of 10 cm and weigh less than 0.5 kg.

Future development goals are to transform UAVs into joint unmanned combat aircraft systems for a wider spectrum of combat missions (SEAD, strike, electronic attack etc.) with an improved data link and stealth capabilities (e.g. the planned Joint Unmanned Combat Air System J-UCAS). Other goals are to reduce weight, increase agility and integrate robotics. New unmanned undersea vehicles (UUV) for submarine warfare are also under development. Between 1990 and 1999, the Pentagon's expenditures for R&D, procurement and operation of UAVs were three billion US dollars. Annual funding for UAVs ballooned after September 2001, reaching 2.23 billion dollars in fiscal year 2007.[42] The US inventory is expected to grow from 250 UAVs today to 675 by 2010.[43]

Currently the Pentagon believes that some 32 nations are developing or manufacturing more than 250 different types of UAV and that 41 countries have some 80 models in operation.[44] UAVs and UAV technology are even more widely available. There is a potential for terrorist groups to use UAVs to deliver chemical or biological weapons, though the possibility already exists that small private aircraft or even models could be hijacked to the same ends.

Precision guided munitions with different ranges (PGM)

The accuracy of both long- and short-range delivery systems has increased dramatically in the last 50 years due to advances in navigation and guidance technologies. In their most recent campaigns, the US military has demonstrated an increasing arsenal of wire-, laser-, and radio-guided missiles, either line-of-sight fired, capable of finding their target automatically with pinpoint accuracy, or steered manually by a person observing the target via TV camera. Laser-guided bombs are guided to the target by "target illuminators", which use laser beams aimed at the target. A laser-guided bomb follows the target signature. It is believed that there are more than 80 missile types in the US inventory that use laser-guidance, GPS, anti-radiation, heat-seeking or terrain-mapping technologies.[45] The Joint Direct Attack Munition (JDAM) package makes it possible to transform a "dumb bomb" into a "smart weapon" accurate to five meters by adding a "GPS/INS navigation kit". One package costs about 15,000 euros and the bomb can be delivered from an altitude of 13 km with a range of 25 km.[46] Military logic sees more accurate ammunition as a means to reduce explosive yield, lower stocks of ammunition and reduce the number of attempts needed to hit a target. Long-range Tomahawk CM can be launched from ships or aircraft and, after a flight of 1,100 km,

[41] D. Fulghum: War from 60,000 Ft., *Aviation Week & Space Technology*, No. 159/10, 8.9. 2003, pp. 54-57.
[42] US Department of Defense: *Unmanned Systems Roadmap 2007-2032*, Washington, D.C.
[43] Ibid, p. 37.
[44] US Department of Defense: *UnmannedAircraft System Roadmap 2005-2030*, Washington, D.C
[45] See G. Chapman 2003, p. 133 (footnote 5).
[46] For details see: R. Garwin: Precision Munition and the systems in which they are embedded- GPS, mapping, high-resolution radar, and non-lethal weapons, in: P. Fogelberg (ed.), *Changing Threats to Global Security: Peace or Turmoil*, Helsinki 2003, p. 111-118.

have an accuracy of 3-5 meters due to the combination of INS, terrain matching and an inertial navigation system, as discussed above.

Table 4: Comparison of precision guided munitions

Type	Name	Accuracy (estimated)	Delivery
Anti-Tank	Dragon	1-2m	Hand held
Cruise Missiles	Tomahawk	3-5 m	Land attack, 880km/h
Missile	ATACMS	5-10 m	MLRS, Ground-launched
Air delivered Bomb	JDAMS	5 m	B-52
UCAV	Predator/Hellfire; J-UCAS	1-3 m	Ground launched

In Afghanistan and Yemen, the US demonstrated a Predator UAV armed with Hellfire missiles to attack alleged al-Qaeda targets. Tragically, innocent people were hit and killed - non-combatants, in several cases.

New weapons effects

The output power of modern day lasers ranges from milliwatts to megawatts for continuous output power, or even petawatts (10^{15} W) for short-pulse lasers. In military terms, lasers with continuous output powers greater than 20 kW are classified as High Energy Lasers (HEL). Output powers in the kilowatt range or above allow the creation of laser beams with potential harmful intensity over distances of up to several hundred kilometers. These beams can be used to heat up targets, which may lead to structural failure of the target object. The first military applications of lasers were developed in the mid to late 1960s, and massive amounts of money have been spent on further R&D since then.[47] At present, a number of research programs is focusing specifically on laser-based directed energy weapons (DEWs). In 2005, the US government alone spent more than half a billion US dollars on DEW R&D. Other industrial countries, such as France and Germany, are also researching HELs. Others, such as Russia, have done so in the past and might still have significant expertise in this field. Lasers may also be used as active sensors. This means that information is gathered using a laser beam which is emitted and then partly reflected back onto the sensor (laser radar). If the intensity of this beam is sufficient to damage a target, a sensor laser may also be used as a DEW.

Several R&D projects for developing HEL are in the pipeline, especially in the US. One such is the Airborne Laser (ABL), which is aiming at ballistic missile defense. The idea is to use a Boeing 747 airplane as a flying platform for a multi-megawatt HEL (a chemical oxygen-iodine laser [COIL] with a wavelength of 1.315 μm) to circle around hostile missile bases and destroy launched missiles in their boost phase.[48] The estimated range of an ABL is between 200 and 600 km.[49] At the moment, some 500 million US dollars are spent per year on the construction of a first prototype. The Tactical High Energy Laser (THEL) is intended for

[47] For an introduction, See: J. Stupl/G. Neuneck: High Energy Lasers: A Sensible Choice for Future Weapon Systems? in *Security Challenges* 1/2005, p. 135-153

[48] G. Forden: Ballistic Missile Defense: The Airborne Laser, *IEEE Spectrum*, vol. 34(9), September 1997, pp. 40-9.

[49] D K Barton et al., Report of the American Physical Society Study Group on Boost-Phase Intercept Systems for National Missile Defense: Scientific and Technical Issues, *Review of Modern Physics*, vol. 76, no. 3, 2004, p. 301 [http://www.aps.org/public_affairs/popa/reports/nmd03.cfm].

point defense. Its primary task would be defending a limited area against mortars shells and artillery rockets.

Military HELs are relatively new and constitute a new type of weapon. As with any new technology, the first important question is whether and how HELs will proliferate in the future. Since there is a great number of laser applications in material processing, one immediate possibility is that proliferation of HEL weapons might be fueled by the existence of industrial lasers. However, the equipment used in laser material processing is relatively expensive and has to be modified significantly before it can be used in a military setting. In addition, the output power of industrial lasers is usually lower than ten kW. The availability of these lasers could nonetheless facilitate research for governments keen on obtaining military HELs. Another key question that needs to be addressed is whether and to what extent the future use of HELs may potentially lead to political instability or the escalation of an existing conflict. One example of a potentially destabilizing event is the deployment of a ground- or space-based laser anti-satellite (ASAT) weapon. Following a successful attack utilizing an ASAT weapon, the country attacked and other countries may be uncertain as to whether a future satellite loss is the result of a technical failure or an attack by a hostile power. In time of crisis, alone the existence of such a weapon might be enough to trigger military escalation. It is interesting to note in this context that the US first tested HELs for use against satellites in October 1997 to examine whether a ground-based HEL could blind their sensors.

Another area of research are non-lethal weapons (NLWs), which would be better dubbed “less-lethal weapons”. They include a long list of new weapon technologies which have been developed or are already deployed, such as strong nets for stopping cars and trucks and electroshock guns that use high voltage darts to “disable people” by temporarily disrupting nerve and muscle function. Another area are chemicals for incapacitating people.

The RMA debate has also involved discussion of other future modes of warfare. In Cyberwarfare the information infrastructure (the Internet, communication networks, distribution nodes, etc.) will become an object of warfare. John Arquila and David Ronfeldt argue that the realm of warfare is Cyberspace itself, which is “an enemy’s electronic sensory, organs, nervous system, or brain.”[50] Two modes of doing harm to critical infrastructure are possible. One is to bomb the physical infrastructure using brute force; the other is for government-employed hackers to infiltrate electronic viruses, trojans or other mal-ware into electronic systems. Anyone familiar with computers knows that the vulnerabilities of commercially available computer systems are a constant fact. Another important aspect of information warfare is the manipulation and distortion of media information in order to ensure that the images presented to the world are favorable to one’s side. Embedded journalists, the use of bomb-mounted cameras to give a misleading impression of “surgical” operations and a one-sided media policy also play an increasing role in warfighting.[51]

Space-based warfare

Space assets such as communication, positioning (e.g. GPS), and surveillance satellites are becoming a prerequisite for the “Revolution in Military Affairs” and the conduct of modern warfare with forces acting on a global or regional scale. In the coming years, more countries

[50] J. Arquila, D. Ronfeldt: *Information, Power, and Grand Strategy*: in: Athená Camp – Section I, Rand Corporation, Santa Monica, p.157.

[51] J. Rantalpelkonen in: E. Halpin et al. *Cyberwar, Netwar and the Revolution in Military Affairs*. Basingstoke 2006, p. 51-81.

will try to obtain these capabilities by developing space technologies in pursuit of their national interests. Outer space is also an important medium for warfare on Earth, but as of now, no "weaponized" satellites (e.g. collision devices, shooters or lasers) exist in orbit. Preserving this situation and avoiding a costly arms race in space is an important task. There are voices in the Pentagon and the US Air Force vigorously pursuing "the option to deploy weapons in space to deter threats and, if necessary, defend against attacks on U.S. interests".[52] US Air Force Doctrine 2-2.1 states that "[s]pace superiority provides freedom to attack as well as freedom from attack". On May 24, 2005 the New York Times reported that "[t]he Air Force is pressing hard to develop defensive and offensive space weapons without adequately considering the potential adverse consequences".

In the Pentagon's Annual Defense Report 2001, we find the following: "Space is now part of the tactical battlefield and its use is growing".[53] As of December 31, 2001, about 200 military satellites were circulating in different orbits around the Earth.[54] The wars in Afghanistan 2001 and in Iraq 2003 clearly showed that space support is a key factor in modern warfare, as is well documented. The 1991 Gulf War was the first war intensively supported by space-based systems. According to the Kosovo After-Action Report 2000: "Space Assets also provided important capabilities. Improved weather forecasting capabilities, enabled by space-based sensors, made the application of aerospace power more effective throughout Operation Allied Force".[55] The use of space platforms is indispensable for the build-up of global "Command, Control, Computer and Communication" (C4I) Systems. Today, US forces are highly dependent on space systems, and the US is the military power that makes the most use of space components for military purposes such as surveillance/intelligence/reconnaissance, navigation, communication, meteorology, early warning, mapping, weapon control, etc. Using its various space components, the US military can collect information and coordinate, communicate, navigate and support a wide range of military operations that permit precise conventional attacks on targets.[56]

Net-Centric warfare

Net-Centric Warfare (NCW) is a new organizational principle that binds together surveillance, command, control and weapons use in a network, cross linked by communication and data interfaces.[57] The main desired *military advantages* of NCW are high information availability through use of high-speed data transmission, sensors, GPS and data fusion to provide field units and command with a full spectrum of battlefield knowledge, thereby helping to enable faster decision-making and immediate execution. At the same time, long-distance weapons and superior reconnaissance should minimize the risk of suffering casualties, while, in theory, precision weapons should help to save ammunition.

Other countries have developed similar concepts: Net-Centric Warfare Capabilities (Sweden), Network Centric Operations (Germany), Air Land Operational Bubble (France). There can be no question but that these concepts are still in their infancy. The 2003 Iraq War involved

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[52] *Report of the Commission to Assess US National Security Space Management and Organization*, Washington D.C., Januar 2001:xii.
[53] W. Cohen: *Annual Report to the President and the Congress*, Washington, D.C., 2001.
[54] J. Pike: The Military Use of Outer Space, in: *SIPRI Yearbook 2002: Armaments, Disarmament and International Security*, Oxford 2002, p. 613- 664.
[55] Department of Defense, *Kosovo After Action Report, Report to Congress: Kosovo/Operation Allied Force After Action Report*, Washington D.C. 2000, p.58.
[56] Pike 2002, pp. 613-664 (footnote 54).
[57] Other terms are C4ISR which is Command, Control, Communication, Computer Intelligence, Surveillance, Reconnaissance.

some elements of NCW, but there has been no serious assessment of the use of NCW in real combat situations. Skeptics point to many problems emerging from elements of NCW, including a lack of standards and constant information overflow, and the vulnerability of modern technologies to countermeasures.

Cross linking RMA elements to enable NCW-type warfare has both military and political consequences. In military terms, transforming force structures by integrating new technologies implies the need for constant field experiments, improved training and simulation and the permanent adaptation of doctrines and tactics. Furthermore, the lines between military, intelligence and stabilization forces become blurred. Politically, there is a risk that the promise of minimizing casualties may lower the threshold at which war is considered acceptable. The emphasis of powerful states on high-tech systems also increases the likelihood of their antagonists' making use of asymmetric responses and countermeasures, such as "unconventional" methods of warfare, thus fuelling the proliferation of new weapon systems and WMDs.

Proving grounds: Iraq and Afghanistan

The war in Iraq 2003 (Operation Iraqi Freedom) and the military intervention in Afghanistan can be called the first proving grounds of US Net-Centric Warfare strategy. The campaign in Afghanistan began with a deployment of special forces and precision air strikes. In Iraq, by contrast, a compact 41-day ground and air offensive was followed by occupation.

The 2003 invasion of Iraq gave a foretaste of what is now called "net-centric warfare": remote sensing, communications, networked sensor platforms gave the US-led coalition an overwhelming military advantage. There were just 20 days between the first attack on March 20, 2003, and the toppling of Saddam Hussein's statue in Baghdad. At the same time, however, one should not forget that the environment and the circumstances were very much in favor of US/UK forces. They had enough time to prepare, the adversary was poorly motivated and the Iraqis' equipment was in bad shape. A balanced analysis of the effects of the military technology is still open. There are reports that indicate that modern technology very often failed. There is no doubt that coalition casualties were very low during the first 20 days (160 soldiers) but the exact number of Iraqi casualties is unknown. During the 1991 Gulf War, around 75,000 are estimated to have died. An Internet database that lists deaths reported in the media counted up to 7,350 deaths as a result of coalition military action during the "major-combat" phase prior to May 1, 2003. In 828 days of US-led occupation, 1916 Iraq coalition casualties were counted.[58] So far, images of surgical strikes are dominating the public perception of the campaign. The long-term effects of the "precision warfare" on the civilian population and infrastructure are generally neglected. Due to the breakdown of the healthcare system and the public infrastructure (water, electricity, sanitation, etc.) in Iraq, a MEDACT Report from 2004 estimates that 100,000 deaths and many more injuries can be attributed to the conflict and violence in Iraq.[59]

One indicator of the ongoing development of high tech means of waging war is the changing ratio in the use of "smart" and "dumb" weapons. Figure 5 shows the changing proportion of "smart bombs" used in operations since Operation Desert Storm in 1991. This is paralleled by the rise in the number of cruise missiles during the last war in Iraq, as shown in Figure 6.

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[58] Iraqi Body Count Database http://icasualties.org/oif/ [accessed on June 23, 2005]. The numbers are based on reports carried in the international media.
[59] Medact: Enduring effects of war: health in Iraq 2004, London (www.medact.org)

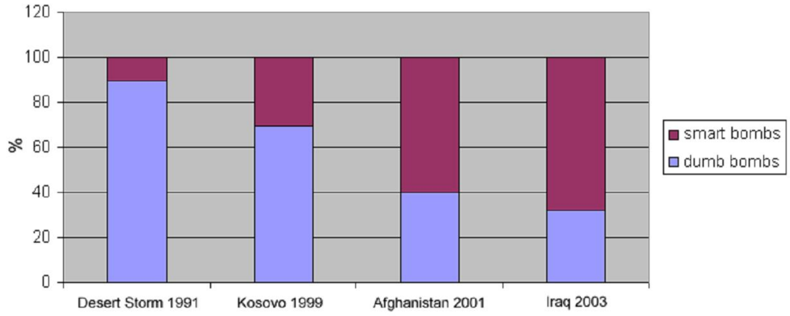

Figure 5: The balance between "dumb" and "smart" bombs is shifting

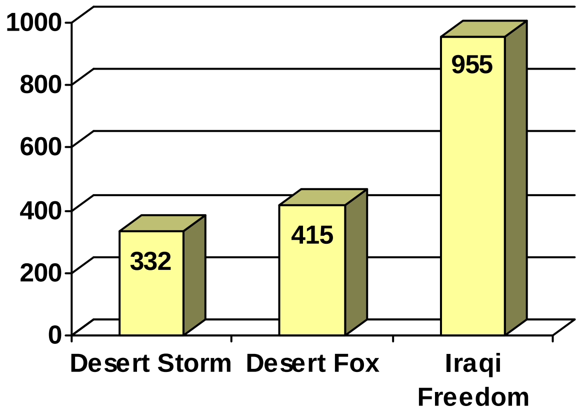

Figure 6: The increasing use of Cruise Missiles in US military campaigns

Collateral Damage – The Myth of Precision Weapons

High tech does not necessarily mean less damage or fewer casualties.[60] Such weapons can cause significant damage on the ground depending on the specific target and the submunition used. For instance, a warhead such as the CBU-87 Combined Effects Munitions, which consists of 202 bomblets, has a destructive radius of more than 150 m. Precision weapons may reach point targets with high accuracy, but even then they can cause huge damage depending on the target. Furthermore there is a common belief that precision ammunition is only deployed against military targets, but who defines a military target? High-tech wars are also often labeled "clean wars" in spite of the increasing deployment of weapons banned (at last in spirit) by International Humanitarian Law. These include fuel-air explosives and cluster munitions – wide-area ammunition delivered with high accuracy. The environmental and humanitarian consequences of other weapon types such as white phosphorus, depleted uranium or thermobaric weapons are not clear in the framework of International Law. The distinction between WMDs and conventional weaponry is blurring further. The destruction area of bombs such as the BLU-82 "daisy cutter" or "fuel-air explosives" is comparable to the direct destruction effects of small tactical nuclear weapons. Here it is likely to be all but impossible to discriminate between military forces and non-combatants.

[60] Two laser-guided GBU-27 smart bombs (2,000 lbs) hit the Amariya Bunker in Baghdad on February 13, 1991 killing approximately 408 civilians. The military believed it was an important command post. "Smarter" bombs still hit civilians, *Christian Science Monitor*, October 2002, [http://www.csmonitor.com/2002/1022/p01s01-wosc.htm].

Improvements in accuracy are lowering costs and risks for air forces, but not necessarily for ground forces and the population. Today, it is possible to destroy any specific target with far fewer bombs (approx. 5%) than 25 years ago. But precision is a highly relative attribute. In the Iraq war, heavy munitions, equivalent in power to some 12,000 metric tons of TNT, were used as a key element of the US military strategy during the first month.[61] Many guided bombs with an accuracy of 13 meters weighed between 225 and 900 kg. Truly safe distances for unprotected people in the open area are between 500 and 1000 meters. There is also no direct correlation between precision warfare and casualties. On the contrary, more precision can mean more deaths, depending on what kind of targets are hit in which environment. In the first month of the US-led invasion in Iraq, it was estimated that between 7,350 and 11.000 Iraqis were killed. Thirty percent of the deaths were non-combatants. This fact does not support the "clean war" thesis. Much more important are weapon effects, the quality of target information and technical reliability. Other estimates of the Iraqi death rate, based on non-representative data, are much higher. In October 2006, medical journal The Lancelet estimated 655,000 excess deaths in the Iraqi population.[62]

During the first 40 days of the high-intensity high-speed 2003 invasion of Iraq "only" 169 US and British soldiers were killed (see Figure 8). In the first year (ending 19/3/2004), 585 US soldiers were killed; in the second year, 936; and the third, 787. The casualties were significantly higher during the battles in Fallujah (see Figure 8). As of April 7, 2008, 4200 British and US Soldiers have been killed. The number of attacks with makeshift bombs against allied forces doubled from 5,607 to 10,593 in 2004. Around half of the Americans killed in 2005 were killed by "improvised explosive devices". These are inexpensive to make and easy to fashion from Iraq's vast stockpiles of munitions. The explosives and shape charges are detonated by triggers such as garage-door openers, infrared beams and timers.[63] Despite spending more to protect their forces, the high-tech army was not able to fix the problem. It is certainly one thing to conquer a country, but another challenge for the military to hold, stabilize and secure such a country. In December 2006, Baghdad was isolated electrically, as insurgents cut off critical high-voltage lines from power plants outside the capital.[64] Nearly 6,400 Iraqi civilians were killed in November and December 2006, thus putting the total civilian casualty figure for the year 2006 at 34,452 dead and 36,685 injured.[65]

Of the 9,270 civilians deaths caused by US-led troops between 2003 and 2005, 6,882 occurred during the period of main hostilities that lasted until the end of April ("mission accomplished"), and 6,616 of these took place in the first 20 days, the period of the main air strikes (figure 7). These numbers do not support the thesis that collateral damage was very low.

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[61] See C. Conetta: 2006 (see Footnote 18)

[62] http://www.iraqbodycount.org/press/pr14.php [January 16, 2007]

[63] E. Schmitt: Pentagon Widens Program to Foil Bombings in Iraq, *New York Times*, February 6, 2007.

[64] J. Glanz: Iraq Insurgents Starve Capital of Electricity, *New York Times* December 2006

[65] Over 34,000 civilians killed in Iraq in 2006, says UN report on rights violations, *UN News Center*, January 16, 2006 [http://www.un.org/apps/news/story.asp?NewsID=21241&Cr=iraq&Cr1=].

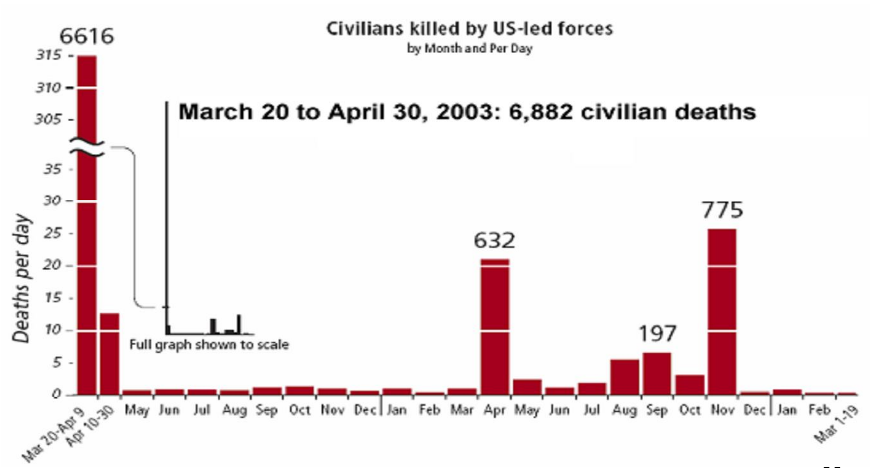
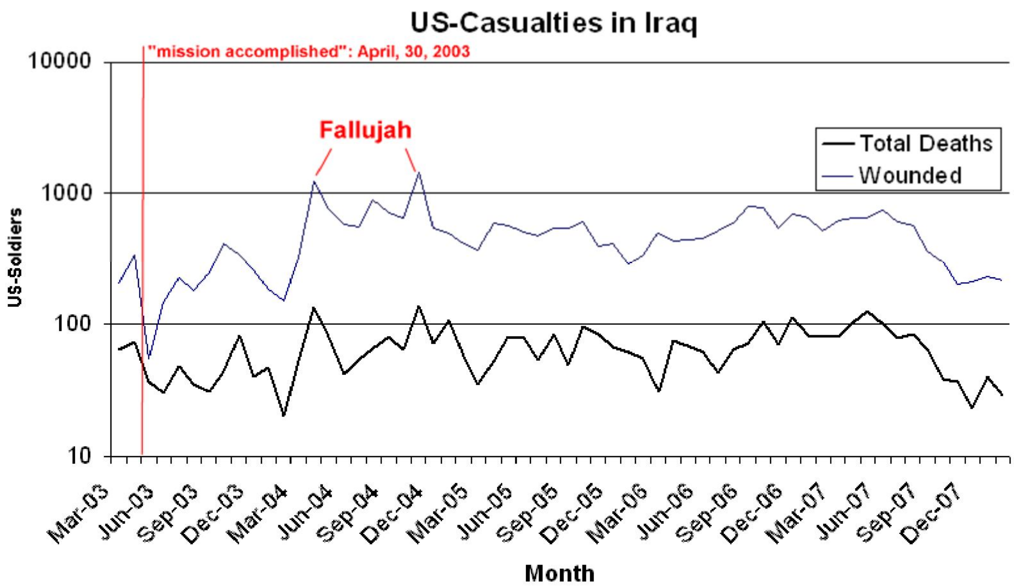


Figure 7: Civilians killed by US-led forces in Iraq per month[66]

Conversely, there were few US casualties during the military offensive attack on Baghdad – 139 US soldiers were killed and 543 were wounded – but by the end of April 2003, the number of US casualties had increased heavily in some months. From May 2003 to the end of February 2008, 3,835 US soldiers were killed and over 28,766 were wounded. Ultimately, this shows that the strategy of net-centric warfare may be effective during main combat operations, but seems to fail during the occupation of a country. Figure 8 also demonstrates that the number of deaths is increasing drastically in urban fighting.



	Main hostilities 20.03.2003 - 30.04.2003	Occupation 01.05.2003 - 29.02.2008	Total
accidental	*31*	*696*	*727*
hostile	*108*	*3139*	*3247*
killed US Soldiers	***139***	***3835***	***3974***
wounded US Soldiers	***548***	***28766***	***29314***

Source: http://icasualties.org/oif/

Figure 8: US casualties in Iraq between March 2003 and February 2008

[66] Iraq Body Count press release on *A Dossier Of Civilian Casualties 2003-2005*, [http://www.iraqbodycount.org/press/pr12.php].

The experiences in Iraq demonstrate that NCW technology might be useful in conquering a country and fighting defenders at high speed. But that other strategies and approaches are necessary when it comes to securing and stabilizing a country.

Complexity and War

War is a complex, nonlinear process of violent interactions where technological superiority is not a guarantee of success. Clausewitz explains this in his own words: “As long as we have no personal knowledge of war, we cannot conceive where those difficulties lie of which so much is said, and what that genius, and those extraordinary mental powers required in a general, have really to do. All appears so simple, all the requisite branches of knowledge appear so plain, all the combinations so unimportant, that, in comparison with them, the easiest problem in higher mathematics impresses us with a certain scientific dignity. But if we have seen war, all becomes intelligible; and still, after all, it is extremely difficult to describe what it is which brings about this change, to specify this invisible and completely efficient factor. Everything is very simple in war, but the simplest thing is difficult. These difficulties accumulate and produce a friction, which no man can imagine exactly who has not seen war.”[67] Alan Beyerchen understood Clausewitz correctly when he wrote: “Clausewitz ought to display a deep and abiding concern for unpredictability and complexity, and consequently to search for ways to express the importance of such matters as context, interaction, effects disproportionate to their causes, sensitivity to initial conditions, time-dependent evolutionary processes, and the serious limitations of linear analysis."[68]

4. Preventive Arms Control

Current developments in the way wars are fought certainly have consequences for the stability and potential extension of existing arms-control regimes. The entire sophisticated conventional-arms-control edifice, which was basically built on quantitative criteria such as agreed ceilings of major weapon systems, may start to crumble in the not-so-distant future if the new elements of modern warfare are not taken into account. The basic concept of the Conventional Forces in Europe Treaty was to achieve “a secure and stable balance” and to eliminate “the capability for launching surprise attack and for initiating large-scale offensive action in Europe”. The CFE Treaty is based on quantitative limits on five major weapon systems for different regional zones. In the future, it will become more and more obvious that the density and effectiveness of military forces cannot be measured simply “in numbers of tanks and fighter aircraft”, but that other categories such as cruise missiles, UAVs and perhaps other robotic systems or autonomous vehicles will have to be included.

During the Cold War, it became clear that the effectiveness of arms-control regimes can be bypassed by technological innovation and proliferation. As defined by Thomas Schelling, the objectives of arms control are[69]:

a) Reducing the likelihood of war,
b) Lowering the cost of preparing for war, and
c) Minimizing the death and destruction that occur if control fails and it comes to war.

[67] Carl von Clausewitz (1780-1831): On War (1832), Book 1, Chapter 7, [J.J. Graham translation London in 1873].
[68] A. Beyerchen Clausewitz, Nonlinearity and Unpredictability, *International Security* 1992
[69] T.C. Schelling, M. H. Halperin (1961). Strategy and Arms Control. New York,, Twentieth Century Fund.

Another important criterion for future weapon use ought to be *Humanitarian Law*, which is designed to limit the reach and the intensity of armed conflict, not to protect the interests of the “haves”. To guarantee the effectiveness of arms control, it has to be transformed in two ways. *First*, arms control in the 21st century has to cope with the technological dynamics by addressing qualitative aspects of armament. This is especially true with regard to asymmetric capabilities. It should be in the interest of many actors to reduce, limit or prohibit specific uses of dangerous weapons such as space weapons. *Second*, arms control has to reflect the profound changes of the post-Cold-War, globalized world. It must therefore become more flexible and more comprehensive and include a wider range of criteria and options. As the very concept of *preventive arms control* suggests, not only quantitative aspects of military forces, but also future technical developments should be taken into account. This widens the scope of arms control into the area of military related R&D. The evaluation of military R&D programs can be performed as part of a systematic arms-technology assessment. Preventive arms control aims to avoid costly and dangerous technology-driven arms races by preventing the deployment of new weapon technologies on the battlefield. A prospective scientific assessment and military-operational analysis of the technology in question are necessary under specific criteria such as:

(1) Adherence to and further development of effective arms control, disarmament and international law,
(2) Maintaining and improving stability, and
(3) Protecting humans, the environment and societies.

Based on such an assessment, a ban or limitations of military usable technology or weapons systems before acquisition or deployment should be considered. It should be considered whether to carry out preventive arms assessment on the following types of weapons:

- Cruise missiles and UAVs,
- Space weapons, nanotechnology, non-lethal weapons. Directed energy systems such as high-energy lasers, microwave weapons.

In addition, various agreements lack effective *verification* procedures, and it would be desirable to invest more in verification and monitoring technologies. The Open Skies Treaty should be revitalized, and additional options such as early warning missions should be integrated. Other areas, such as the protection of forces and civilian populations or the improvement of “identification friend-foe” systems to avoid friendly fire, are also subjects of ongoing research. The key task for the “globalized world” is first and foremost to develop strategies to win the “hearts and minds” of the people in zones of violent conflict. The inclusion of civil society is fundamental and armed forces should seek to enter into dialogue with civil society before it comes to an uncontrollable escalation of violence.

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