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Changing characteristics of warfare and the future of Military R&D

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ABSTRACT

Wars have been a part of humanity since prehistoric times, and are expected to remain an important component of future human societies. Since the beginning of the history wars have evolved in parallel with the changes in Society, Technology, Economy, Environment, Politics and Values (STEEPV). The changing circumstances unavoidably affect the characteristics of warfare through its motivations, shape and size. Armies have adapted themselves to these changing characteristics of warfare through Revolutions in Military Affairs (RMAs) by introducing new military concepts and technologies. Based on the overview of the evolution of military technologies and concepts as a response to changing conditions, the aim of the present study is to anticipate what and how future technologies and concepts will shape warfare and drive impending RMAs. To answer this question, first the RMA literature is reviewed within a broader historical context to understand the extent to which military concepts and technologies affected the RMAs. Then, a time-based technological trend analysis is conducted through the analysis of military patents to understand the impact of technological developments on military concepts. Following the historical analyses, two scenarios are developed for the future of military R&D based on 'concept-driven' and 'technology-driven' factors. The article is concluded with a discussion about the implications of future scenarios for military R&D, and likely RMAs through the changes of concepts and technologies, and possible consequences such as transformations in organizational structures of armies, new skill and capacity requirements, military education systems, and decision-making processes.

1. Introduction

Wars have been a part of human life since prehistoric times and they are expected to play an important role in the future. The shape, characteristics, and size of wars have changed drastically over time due to transformations in Societies, Technologies, Economy, Environment, Politics and Values/Cultures (STEEPV). The military's response to changing characteristics of warfare has been through 'technology-driven' and 'concept-driven' approaches. There have been times when new technologies enabled armies to develop new war concepts; and times when new concepts required the development of new technologies. In both cases, armies have aimed to adapt themselves to changing characteristic of warfare through military Research and Development (R&D), which is called "Revolution in Military Affairs" (RMA) (Krepinevich, 1992).

Historical transformations show that from the battle of Greek phalanxes to nano-soldiers' network-centric warfare, there have been enormous shifts in the perception of threats and security. The key challenge for armies has been to remain resilient under changing circumstances of warfare due to transformations in STEEPV systems by adapting themselves constantly through RMA. The key research questions of the present study are:

1. Why and how have military technologies and concepts driven RMA as a response to changing conditions?
2. What are the emerging technologies and concepts, which may change the nature of warfare?
3. How can the future military R&D agenda be configured to respond to changing conditions?

To answer these questions, the second section of the paper begins with a review of the RMA literature within a broader historical perspective. First the RMA concept is introduced, and then key drivers for RMA are discussed. Building upon this background, Section 3 describes the research methodology with the use of a combination of literature review, patent-based technology trend analysis and scenario techniques to investigate the emerging military technologies and concepts. A research model is presented to illustrate how the key research question is addressed.

Section 4 of the paper starts the analysis with a review of the generations of warfare. The aim is to understand the changing characteristics of warfare over a long period of time and how armies historically responded these changes. Thus, it aims to highlight the relationships between military concepts and RMAs, which in turn have implications for

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military R&D and affected the development of military technologies. Section 5 takes a closer look at the developments in military technologies as a driver for RMAs and discusses the implications of technologies on military R&D. This is done through a patent-based technological trend monitoring across time. While the review will indicate the 'concept-driven military R&D', the technological trend analysis will indicate the 'technology-driven military R&D'.

Following the discussions on the implications of conceptual and technological developments on RMAs and military R&D, Section 6 of the paper takes a prospective look at the longer term future by formulating two scenarios shaped by the 'concept-driven' and 'technology-driven' factors. The scenarios consider the changing military concepts and anticipated technological developments within a broader STEEPV context, and discuss how these may change the nature of warfare. Then, the paper is rounded off in Section 7 with a discussion about the implications of the future scenarios for military R&D, and possible consequences such as transformations in organizational structures of armies, new skill and capacity requirements, education systems, and decision-making processes, which may characterize future RMAs.

2. Background

"War is a murder, unless the use of the most recent peaceful means."
[October 4th 1922/Mustafa Kemal Atatürk (Founder of Turkish Republic)]

As in the words of Atatürk, the population-centric perspective should be the more prominent motivator for war studies. Conflicts and wars have been in human life in all ages with various motivations such as seizing land, killing an enemy, or changing regimes, and they will continue in the future with similar or somewhat varying motivations. The changing motivations, shapes and sizes of wars required the introduction of new military concepts and technologies and forced armies to reform themselves through RMAs.

The RMA phenomenon can be traced in the literature beginning in Napoleonic times. Particularly starting from the 19th century, more systematic efforts have been made to adapt armies to changing characteristics of warfare through technological innovations in defense industries and organizational innovations in military concepts. Blasko (2011) described the relationship between defense technology and military concept as a "chicken-egg problem" (p. 355). Hence, there is no clear-cut distinction between the two; however, one usually drives the other interchangeably. Machine gun, airplane, submarine, and the Dreadnought class of ships were among the technologies, which altered the military concepts in the mid-19th and the early 20th centuries. There were significant changes in war concepts due to technological developments.

During WWI and WWII from 1917 to 1939, the exploitation of internal combustion engines, improved aircraft design, and radio and radar technologies made the blitzkrieg, carrier aviation, and strategic aerial bombardment possible. The difference between WWI and WWII itself is an important example of technological developments and the eventual change in military concepts. Whereas WWI indicated the characteristics of a more conventional war, WWII witnessed the synchronization of air, land, and sea forces. A number of technology-driven innovations can be found in WWII. For instance, the use of railroads, telegraph, warships/battleships, rifles and artillery transformed the concepts of the military fundamentally. Military forces were organized, equipped and employed to achieve maximum military effectiveness by using new technologies. Finally, the amplitude of nuclear violence with the use of nuclear weapons helped to demonstrate the decisive role of technology in warfare.

After a couple of decades, during the Vietnam War, the US confronted a new style of warfare called "guerrilla warfare" or "asymmetric warfare". The need for tracing and the rapid deployment of forces was the major driver that shaped the US army's strategy. This changing war concept led to the use of helicopters at the battlefields in an offensive way for the first time, which can be considered an example of when the recognition of operational necessities shaped the use of technology in different or maybe more innovative ways. This search of innovative ways leads the nations to revolutionize their armies with the help of technology which was called Revolution in Military Affairs later.

RMA that can be said is explicitly rooted in Russia's Military Technological Revolution concept during the 1980s, when the Soviet hegemony in the world was mainly based on its superior military technology rather than economic strength. According to Chiang (1990), in the uniformed military in the post-Stalinist era, the General Staff has been in the center of weapon systems development, integration, procurement, and deployment, in addition to its normal military forces' planning and development. Therefore, it can be assumed that Soviet military system institutionalized the technological military system for several decades. This centralized structure could explain their shorter cycle in utilizing novel technologies and deploying new systems and also it could explain the logic of technological revolution in military affairs, because they embedded the technological developments into the military institutions. Likewise the Russian RMAs, the US has transformed its army around the same times due to the changing war concepts. They changed their understanding of warfare with a technological viewpoint and competitive superiority and their most prominent application was during the First Gulf War. According to Krepinevich (1992)'s report, the Gulf War victory clearly revealed the importance of the RMA concept.

Nearer to the present time, the likelihood of future world wars or other large scale mass destructive potential wars has decreased considerably. However, it has also been observed that the development of military technologies has continued at a growing rate. In parallel, the destruction potential of weapon systems has increased considerably. A technologically-equipped soldier today is more powerful than a battalion from Napoleonic times. Besides the technological developments, there have been considerable changes in the public perception of wars. The visibility of wars has increased dramatically compared to the Napoleonic times. Today, war scenes from all over the world are captured an ordinary mobile phone cameras and then shared with the rest of the world through the Internet. Thus, the society is getting more and more exposed to wars and loss of human lives, and is increasingly more sensitive towards war and less tolerant of fatalities.

The presence of a powerful military with an increasing visibility and social engagement are expected to be among the factors, which will transform the logic of military discourse. For instance, Kaldor (2010) proposes a shift in military discourse from border protection towards population security. The practical application of this and further ideas to transform armies requires changes in military concepts and technologies. Before discussing how those concepts and technologies may look in the future, the paper will begin with the review of the historical analysis of change in military concepts and an analysis of longitudinal data of military patents to identify technological trends. The review and technology trend analysis will provide input for the discussion on the future character of warfare.

3. Methodology

The aim of this study is to discuss how the characteristics of warfare are changing over time due to a number of transformations in STEEPV systems, and how the military adapts itself to this change through concept-driven and technology-driven responses, which may shape military R&D and thus introduce new RMAs. The proposed research model is illustrated in Fig. 1.

With regards to the proposed research model, the research methodology involves a combination of literature review, bibliometric analysis, patent analysis and scenario techniques.

The current paper reviews the RMA literature with a broader historical perspective to understand the changing characteristics of warfare. A closer look is taken at the evolution of military concepts and

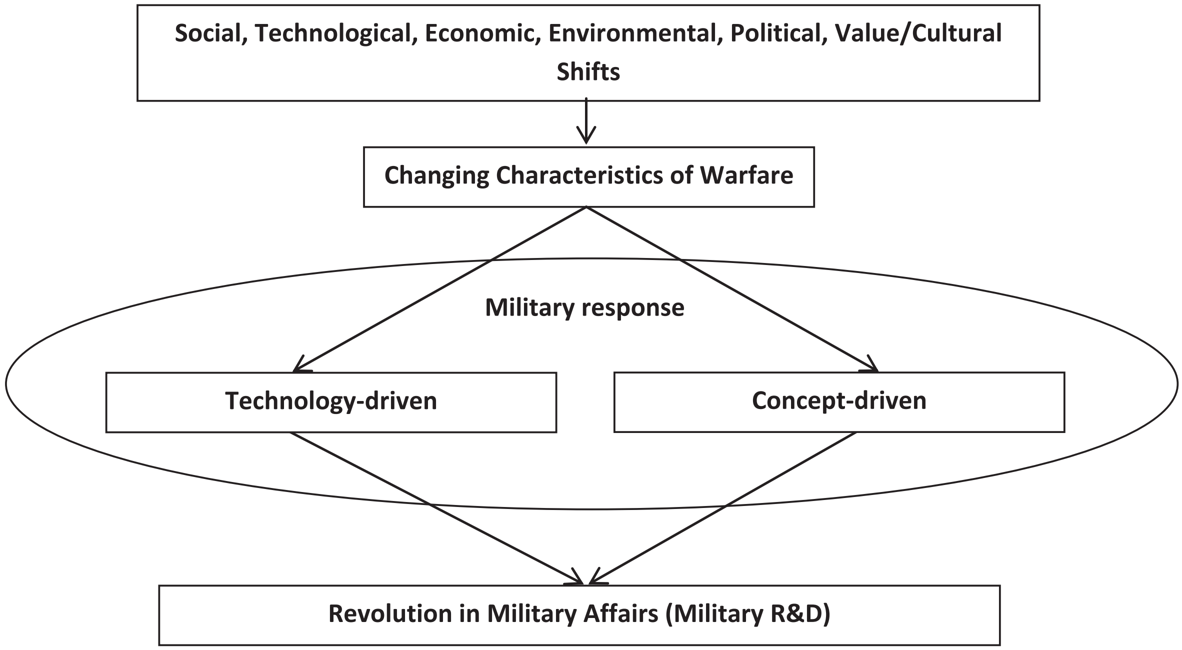

Fig. 1. Research model.

technologies throughout history and how they have shaped each other and co-evolved. Where the existing literature regarding RMA and history of military technology remained insufficient to identify the characteristics of future warfare, bibliometric analysis was used. Norton (2008) defines bibliometrics as the measurement of texts and information. Bibliometrics have been used to understand the past and forecast the future developments by exploring, organizing and analyzing a large amount of data to identify hidden patterns and trends (Daim and Suntharasaj, 2009). For the purpose of the current study, first, key concepts regarding the new types of war were extracted from the existing literature in the form of keywords. Then, these keywords were used for searches in the Web of Knowledge publication database. Frequencies of war-related keywords are calculated to see the overall direction of development of warfare in the literature.

Patent analysis has been used at length to understand the invention and innovation processes (Schmookler, 1966; Griliches, 1990). There are a number of different uses patent data such as the analysis of the time-lag between the allocation of research funds and patents issues (Daim et al., 2007); to assess innovation diffusion (Nelson, 2009); or predicting the future directions of technological development (Choi et al., 2011). A patent-based trend analysis approach is proposed in the current study. The patent analysis was done with the use of the Vantage Point software (Watts et al., 1997). The contribution of this study is the analysis of the changing characteristics of warfare and the shifting trends of military technologies through publications and patents. Both bibliometric and patent analysis use big data (i.e. large number of publications and patents) to understand the trends based on the collective intelligence gathered by a large number of researchers and innovators. The investigation on the changing characteristics of warfare (Section 4) and development of military technologies across time (Section 5) will help to address the first research question on why and how military technologies and concepts have driven RMA as a response to changing conditions. This will constitute a basis for the development of future-oriented scenarios, which will address the second research question regarding emerging technologies and concepts, which may change the nature of warfare in the future.

The scenario method has been used frequently, starting with the work done by Herman Kahn during the Cold War period. As a military strategist and systems theorist, Kahn used scenarios first for military purposes to think about the consequences of a nuclear war (Kahn, 1965; Kahn and Wiener, 1967). Following his work, scenario method has been used for multiple purposes in a wide variety of areas ranging from science, technology, economy and policy. Scenarios gained further credence in the corporate world with the work of Wack (1985) and Schwartz (1999). Wack (1985) defines scenarios as "*a discipline for rediscovering the original entrepreneurial power of creative foresight in the context of accelerated change, greater complexity and genuine uncertainty*". Scenarios provide alternative images of the future in an internally consistent way. However, they should go beyond providing future images towards informing policies and strategies for action. Schwartz (1999) states that "*ultimately, the end result of scenario planning is not about a more accurate picture of tomorrow, but better decisions about the future*". The present study develops two scenarios, namely 'concept-driven' and 'technology-driven'. The scenarios will help to describe to what extent military R&D might be influenced by the changing military concepts and technologies. A discussion will be undertaken to address the third research question on how the future military R&D agenda can be configured to respond to changing conditions.

4. Changing characteristics of warfare

Wars have always been in human life from the ancient times to the present. However, the motivations, shapes and sizes of wars have changed drastically in time. Clausewitz (1968) defines war as: "*an act of violence to compel our opponent to fulfill our will*" (p. 2). This definition highlights some key components of a war such as 'opponent', 'violence' and 'will', which refer to the 'nature of war'. As the nature of war has changed, so have its definitions. A recent definition from Kaldor (2010) reflects the key characteristics of today's war: "*War is an act of violence involving two or more organized groups framed in political terms*". This definition, as Kaldor asserted, is a new interpretation of Clausewitz (1968) and can describe the new character of warfare with increasing number of actors involved.

Whereas the broad conception of war, 'violence' has remained the same across time, the 'means' and 'ends' of wars have been fundamentally different from each other due to changing STEEPV systems in wider contexts and concepts and technologies used in wars. This transformation over time indicates the 'changing characteristics of warfare'. For instance, during the 16th and 17th centuries 95% of the great powers in the world were involved in wars. This number decreased to 71% in the 18th century and 29% in 19th century (Lebow, 2010).

The dispersion of these conflicts to other countries were analyzed by the Peace Research Institute Oslo and based on their database (http://www.prio.no), the end of the Cold War has not eliminated armed conflict. According to Gleditsch et al. (2002), a total of 115 armed conflicts have been recorded for the period 1989–2001 and in all or parts of 2001, 34 conflicts were active in 28 countries. Another study is performed by Hegre et al. (2012) for prediction of the future of armed conflicts and they propose that global incidence of conflict is likely to continue to decrease from the current level and probably be reduced to about half of the present number of conflict countries in 2050. They also conclude that over the next few decades, an increasing proportion of conflicts will occur in East, Central, and Southern Africa as well as in East and South Asia. This can be interpreted as the armed conflict will be a part of human life in future.

Apart from these statistics, it is claimed that when the history of warfare is analyzed, three generations can be distinguished (Lind et al., 1989; Hammes, 2005):

1. First generation can be described as the 'tactics of line and column' and it reflects its age with the calculation of number of barrels. Quantity was equal to power at that time and keeping the line meant maximizing the firepower.
2. Second generation's distinction came with the usage of technology, mobilization, and the power of indirect fire (Artillery). The change of power from manpower to mass power differentiated these first two generations.
3. Third generation is identified with Blitzkrieg. According to Lind et al. (1989), in contrast to second generation's technology-driven aspect, the motivation in the third generation was 'ideas'. German's superiority in tactics was seen as a radical development. Lind et al. (1989) explained this superiority with an offensive viewpoint as "*attack relied on infiltration to bypass and collapse the enemy's combat forces rather than seeking to close with and destroy them*" (p. 23) and with defensive viewpoint as '*the defense was in depth and often invited penetration, which set the enemy up for a counterattack*'.

It is noteworthy that the distinctions between generations were made based on the dominance of military concepts and technologies. Whereas the second generation represented a technology-driven approach, the third generation indicates the characteristics of a concept-driven warfare. Whether the generations can clearly be divided as concept-driven and technology-driven can be argued. It is almost impossible to give an absolute judgment on this issue. The current study aims to understand the intensity of concept and technology usage and assumes that both are instrumental in the changing characteristics of warfare.

The aforementioned generations are mainly concerned with the historical evolution of wars, but how about future ones? Lind et al. (1989) and Hammes (2005) propose a 'Fourth Generation Warfare'. According to their views, Fourth Generation Warfare can be seen as a twilight zone- between war and peace, between civilian and military, between tactics and strategy. However, there are criticisms about their study of the fourth generation as it does not cover the present situation (Junio, 2009) and lacks scientific and historical roots with a poor theory (Freedman, 2005). Both Junio and Freedman accept that the characteristics of warfare are changing, but whether this change can be considered fourth generation or not is the new discussion point among the international security scholars.

Because of the ambiguity in literature about future warfare, the present study tried to identify the first "weak signals" (Saritas and Smith, 2011) of the characteristics of future warfare. For this purpose, the bibliometric analysis technique was used. A set of keywords/phrases were extracted referring to future war concepts. The final list of keywords/phrases was created with expert consultations and included: 'Counter-insurgency', 'Asymmetric warfare', 'Space war', 'Cyber war', 'Information warfare', 'Network-centric warfare', and 'Low-intensity conflict'. Each keyword/phrase was searched in the Web of Knowledge publication database and the frequencies of war-related keywords were calculated. The search was limited to the publications from 1989 to present as the year 1989 is widely considered in the literature as the beginning of fourth generation debate in the literature presented above. The publication frequencies of future warfare approaches can be seen in Table 1.

As the table illustrates, from 1989 to present, the most widely discussed issue among scholars is 'counter-insurgency'. The nature of insurgency and counter-insurgency studied by Lindsay (2013) and this subject were discussed by comparing the RMA concept in his study. According to Lindsay (2013), RMA is technology/network centric and counterinsurgency is 'population centric' and the technological advantages of the RMA in conventional combat are not as productive as expected when the war is among people. Whether the wars are changing as conflicts between people, the information and communication technologies play an important role for counterparts.

As can be seen the second most discussed issue is "Information Warfare" and the third one is the "Network-Centric Warfare" concept. Having superior power to use, manage, and control information networks is becoming an important subject when dealing with insurgency. These interpretations may be more elucidative as demonstrated in Fig. 2.

When the graphical representation of future warfare publications is analyzed, it can be seen that the literature emphasizes the concepts of counterinsurgency, network-centric warfare, and information warfare. This demonstrates that future wars are anticipated to be human-centered within the context of information intensive networks. This anticipation reveals another question as to how nations can be successful in this kind of war. The publication analysis may give some weak signals about a remedy also. When the trend of the warfare concepts is analyzed it can be seen that the focus of scholars is on network studies and information-intense approaches. It can be proposed that the combination of these approaches may be helpful for countries when directing their funds for their citizens' security.

5. Military technology developments

Studies on the 'history of military technology' gained importance between historians in the 1980s (Roland, 1993). Up to the 1980s the trend of the military technology studies, which was pointed out by Roland (1985), gives insights regarding the relationship between science, technology, and war. Particularly, van Creveld's (1989) book is generally accepted as the seminal work in the history of the field of military technology.

In his book, van Creveld (1989) classified military technological developments into four stages from 2000 B.C. to present. The first stage was observed from 2000 B.C. to 1500 A.D. During this period, most military technology derived its energy from muscles of men and animals. Finding some bronze and silver weapons and wheeled vehicles did not change the way of war significantly. Van Creveld described the second stage, which took place in the period of 1500 to 1830, as the age of the machines. First, firearms and later internal combustion engines were the revolutionary equipment of this period. Armies became more mobilized, which increased the need for coordination of equipment and communication. Therefore, the third stage from 1830 to 1945 was called as "the age of systems". Van Creveld emphasized the integration of technology into complex networks. Using tanks, railways, highways, and improving means of logistics made this stage more complex with increasing integration. Finally, van Creveld described the period from 1945 to present as the "age of automation". After 1945, rapid developments in technological innovations had increased the amount of information needed for running military units, making decisions, carrying out missions, and conducting operations, campaigns, or wars. This vast amount of information naturally required 'computerization' and a 'network structure' to disseminate information to the soldiers in the theatre.

Table 1
Publication frequencies of types of future warfare approaches.
(Based on Web of Knowledge Data, Access Date: 20 April 2013).

	Counter-insurgency	Asymmetric warfare	Space war	Cyber war	Information warfare	Network-centric warfare	Low-intensity conflict
1989	9						3
1990	12						7
1991	8						9
1992	9						
1993	12						4
1994	3				2		3
1995	4				4		
1996	3				14		
1997	6		2		12		5
1998	9				15		3
1999	3				14		3
2000					18	6	
2001		2			19	15	2
2002	4	4			17	12	6
2003	10	3		3	26	25	2
2004	9	5		2	12	28	2
2005	14	5		5	8	35	6
2006	19	9		3	8	33	3
2007	22	7		3	18	34	3
2008	41	9	3	4	21	22	
2009	40	15		14	23	24	2
2010	68	10		20	29	17	4
2011	64	7		16	11	11	
2012	67	5		19	12	5	4
2013	5						
Total	441	81	5	89	283	267	71

In another study, Hacker (2005) analyzed Western military technology in the period of 1850–2000. In his study, Hacker asserted that the coupling of science with military technology began only in the 19th century. According to him, before 19th century, technical practice often influenced science more than scientific research did technology.

Hacker (2005) also posited that military technology changed far more quickly than military organization and doctrine before the World War I. Moreover, he acknowledged that the most striking feature of the late 19th and 20th century was an extraordinary expansion of productive capacity. Because of increasing mobility, the most important technologies were logistics, communication and transportation in this period. Hacker defined “generalship” as displaced with industrial engineering and attrition became the recipe for victory.

Hacker (2005) called World War II a “manoeuvre war”. Because of this, he asserted that the military doctrine and tactics caught up with technological change in World War II. From World War II until the Cold War period, the old balance had been reversed and military technology proliferated as applied science became ever less distinct from scientific engineering. World War II taught military planners that science-based technological innovation had become the mainstay of military preparedness. The dominance of American military policy became permanent during this period and the nuclear power was used as a deterrence instrument.

The late 20th century revolution period proved that technological innovation was not decisive alone, because new weapons required new doctrines, tactics, and organization. The importance of the Internet and information processing represented other aspects of computer-related technological developments. Military support for microelectronics and computers generated different technological capabilities that had major impacts on waging war. Computers and sensors had expanded the soldiers' view of the battlefield and increased the ability of command and control capabilities. By integrating precision-guidance munitions into the network of command and control systems, the locate-track-target-fire chain was completed.

The literature review makes it clear that military technologies are evolving towards more digitalization in parallel with the progress towards knowledge-based and learning societies. In order to characterize this evolution better, a patent-based trend analysis was conducted. All patents in the Derwent patent database (from 1962 until present) were searched with ‘military’ or ‘defense’ keywords. The search yielded 37,281 registered patents. A content analysis through these patents generated 525,327 phrases in the field. Through the Natural Language

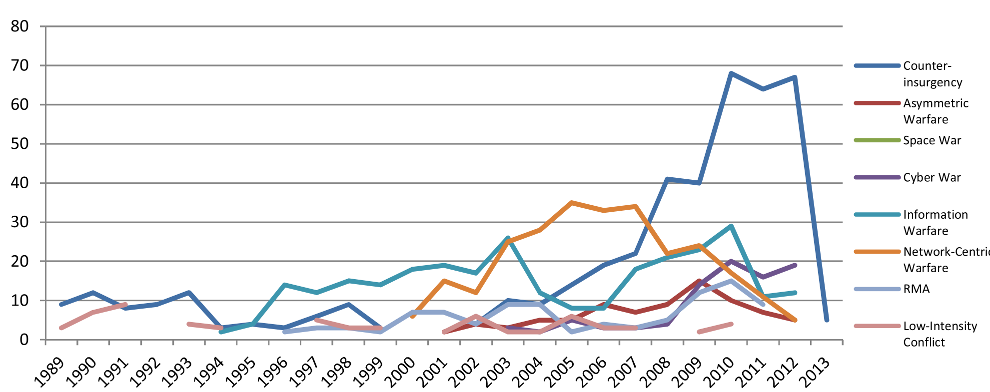

Fig. 2. Graphical representation of future warfare publications.

Processing function of the Vantage Point software and expert consultations, this number was reduced to 243 of the most frequent phrases. With the use of the Principal Components Decomposition function of the software, the number of phrases was reduced to 148 by clustering. Following various iterations of this process along with further expert consultations; the fourth round resulted with 38 phrases with the coverage rate of 39% of the total number of patents generated (i.e. 37,281). This rate of representation was considered to be sufficient in terms of cost-efficiency and high level of descriptive capacity of the whole set of phrases. The final list of 38 phrases is given in Table 2.

When Table 2 is analyzed, it can be seen that the patents are mostly about vehicle, energy, sensor and communication technologies. However, in order to analyze trends, the distribution of these terms on a timeline will also be more helpful.

Fig. 3 was prepared for analyzing this trend. It can be seen in Fig. 2 that the number of patent registrations remained pretty much stable from 1962 until the late 1990s. From the year 1998, however, a dramatic increase is observed in almost all of the areas selected above.

The sudden increase in patent registrations in 1998 and 2000 can be interpreted as the beginning of a technology-intensive period in military R&D, which continues to rise at an increasingly steep rate until present.

In order to make a more detailed analysis, the 38 phrases were first clustered into four major categories including:

1. Detection and Sensor Systems
2. Military Vehicle Systems
3. Energy and Communication Systems
4. Weapon Systems

Table 2
Key phrases identified for patent analysis.

	# Records	Phrases
1	2442	Military vehicle technologies
2	1889	Energy sources and technologies
3	1343	Military aircraft
4	1311	Mobile communication technologies
5	1281	Sensor systems
6	1264	Low power consuming systems
7	1075	Image systems
8	985	Military personnel
9	925	Wireless communication system
10	542	Military armored vehicle
11	526	Track and surveillance system
12	466	Military communication system
13	403	Command and control systems
14	402	Industry application
15	394	Global position system GPS
16	380	Detection system
17	368	Marine vehicles
18	344	Weapon systems
19	303	Night vision systems
20	252	Unmanned aerial vehicle
21	251	Defense missile and guidance system
22	242	Rescue and disaster operation technologies
23	237	All-terrain vehicle
24	220	Explosion devices
25	216	Small arm
26	212	Composite material
27	173	Electric/hybrid vehicle
28	149	Biological warfare agent
29	145	Military tank
30	137	Laser system
31	133	Chemical warfare agent
32	124	Space vehicle
33	102	Target locator
34	90	Unmanned ground vehicle
35	57	Military helicopter
36	55	Flight simulator
37	51	Grenade launcher
38	43	Improvised explosive device

Second, due to the low and stable number of patents with a lack of a significant change in the nature of trends, the patent analysis was limited to the period starting from 1998/2000 until the present, as this represents a major transformation in military technological development. Below, each of the clusters will be presented cumulatively with the interpretation of trends occurring in them.

The cluster of Detection and Sensor Systems is indicated in Fig. 4 with the trends in each component of the cluster.

As the figure illustrates, a number of patents have been registered in sensor systems and it is anticipated that these figures will continue to grow in the future. This is followed closely by the image systems. The joint increase in sensor and image systems is noteworthy. Although not at the same rate, the other systems in the cluster also indicate an increasing trend in the number of patents registered.

The results of the patent analysis in the Military Vehicle Systems are indicated in Fig. 5.

The figure illustrates that in this cluster, the number of patents on military aircraft technologies is considerably high. This trend is followed by military armored vehicles with an increasing number of trends more recently. The dramatic increase in the number of patents registered in electric/hybrid vehicle and unmanned aerial vehicle categories are noteworthy in the Military Vehicle Systems cluster.

Increasing demand for mobility brings the need for and greater interest in energy and communication technologies that are required by mobility. Fig. 6 illustrates the trends in the Energy and Communication Cluster identified with the patent analysis.

This cluster can be analyzed from the perspectives of both energy and communication technologies. The rapidly growing number of patents for energy sources and technologies indicates an increasing interest in this area. Besides developing new energy sources, it is also noted that research activities are conducted to increase the energy efficiency of existing military equipment and low energy consumption emerges as a design criterion for newly developed products. From the communications point of view, considerable efforts are made on the development of mobile communication technologies to support next generation military vehicles and equipment. In parallel, it is observed in the figure wireless systems are gaining more and more importance and are used in a complementary stance with the other communication technologies.

Weapon systems are critical for military forces. The patent analysis on the Weapon Systems cluster revealed the trends illustrated in Fig. 7.

It is striking that the number of patents registered in the Weapons Systems cluster from the beginning of the 2000s is relatively low compared to the other clusters. The patent data reveal no significant trend in this group of technologies. The emergence of improvised explosive devices from 2006 onwards is considered to be due to the increasing use of these technologies for defense purposes in an asymmetric war.

The synthesis of historical analysis and patent-based military technology trend analysis gives an opportunity for a more aggregated analysis from a wider perspective based on how social and economic developments, and military technologies and wars have evolved and shaped each other. Fig. 8 shows, four generations that can be distinguished throughout history.

The generations given above are not limited to certain periods of time in history intentionally due to the heterogeneity of developmental patterns across the world - i.e. while some counties in the world still host agricultural societies, some others progressed faster on the development path and became “Network Societies”. Therefore, the figure does not intend to make a generalization on periods of evolution, but rather aims to indicate the diversity in the levels of development in society and economy, military technologies, wars and success indicators for wars. Tensions and conflicts may occur within these groups as well as between them. This may result in asymmetric or hybrid warfare conditions, which are considered to be one of the key determinants of future war concepts and technologies.

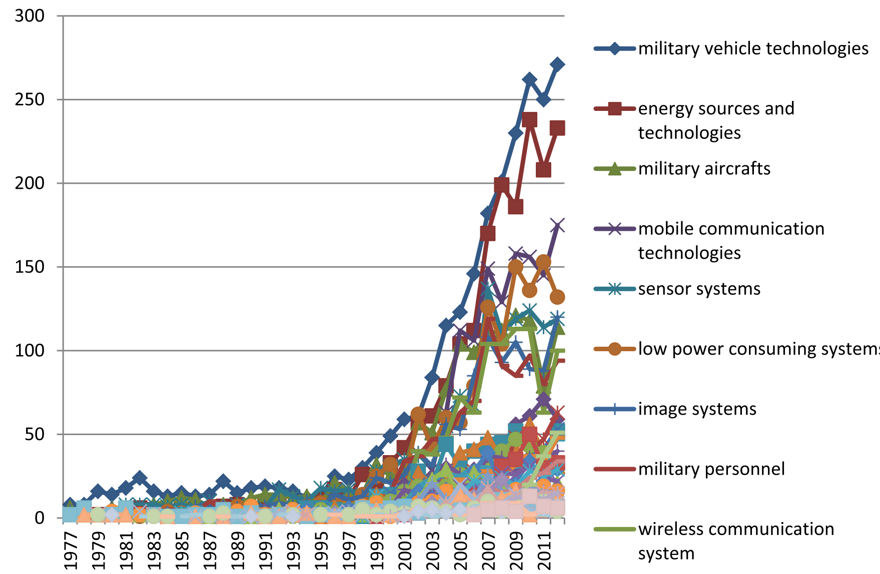

Fig. 3. Trends for military technology patents.

6. Scenario planning for the future war environment

Based on the analyses and findings above, this section will begin with a summary of the key characteristics of the future war environment. Among the most prominent trends in the evolution of military concepts, the following ones can be mentioned:

- Wars are taking place closer to the areas inhabited by civilians, and military operations are increasingly taking place in residential areas. There is less tolerance for the loss of the military personnel and civilian lives. With the growing role of media and social networking technologies, societies are more exposed to losses. Therefore, the increasing number of the death toll overturns social, and thus political, support for armies. Lower or no negative impact on human lives and settlements is becoming a key success factor for military operations.
- The security and sustainability of energy sources can be considered one of the key determinants of success in military operations. Due to the diversity of war environments, concepts and technologies mentioned above, military operations may take place in a wide variety of conditions. This may require military equipment to be suitable for the use of more than one energy source to ensure their viability for an extended period of time.
- The meaning and role of leadership in armies is also changing. In the past, leadership referred to 'power', however, in the current war environment, it refers more to 'common wisdom'. Due to the increasing flow of information from a number of sources and growing complexity, it is difficult, if not impossible, for a single leader to make correct decisions in a limited timeframe. It is expected that satellite and sensor systems, artificial intelligence and advanced data analytics will play a greater role as decision support systems. Therefore, next generation leaders in the army will go beyond sole commanders, but towards becoming 'CEOs of the knowledge economy'. Consequently, creative and flexible thinking, collaborative behavior, skills of collective intelligence and the ability to work with Information and Communication Technologies are becoming crucial qualifications for future military leaders.

The trends on changing military operation environment, transformations in social and political attitudes towards war, the increasing need for secure and sustainable energy sources, the role of ICTs, and changing profile of military leaders are considered to have far-reaching implications for future war concepts and technologies. These implications will be captured and discussed in two scenarios. The first scenario will consider the future of warfare from a 'concept-driven approach', where the concept will be a key determinant for military R&D and technology development. The second scenario will consider technology as a key driver of change and will discuss the impacts of technology on military concepts with a 'technology-driven approach'. Within this framework, the 'concept-driven scenario' can be considered the demand-side of the change process. Socioeconomic and political transformations in the world require new concepts to be developed to deal with new needs and expectations of society in line with the changing shape, size and actors of warfare. The 'Technology-driven scenario' will bring a supply-side aspect into the discussion, by investigating

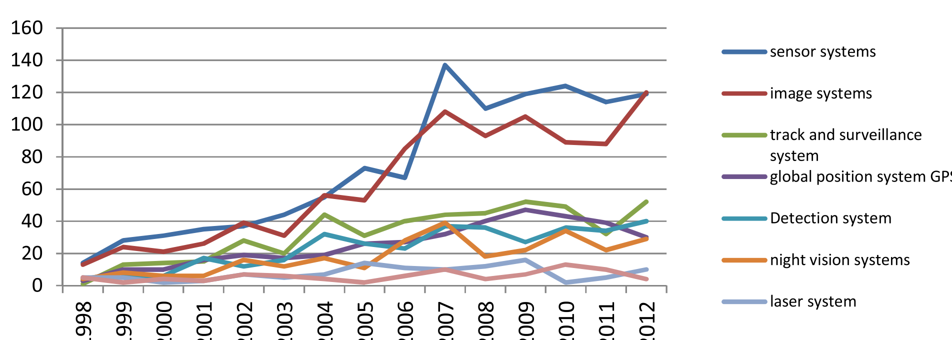

Fig. 4. Trends in the Detection and Sensor Systems cluster.

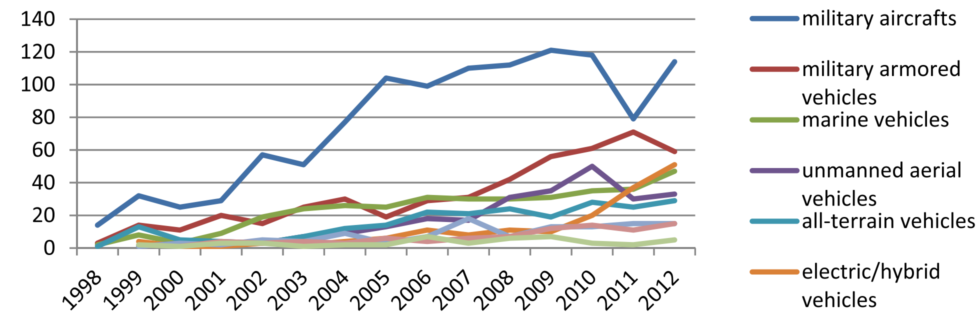

Fig. 5. Trends in the Military Vehicle Systems cluster.

emerging technologies and how these will help military gain new capabilities. Both scenarios are described in the next sections of the study.

6.1. Concept-driven scenario

In a globalized world, where physical boundaries are diminishing and increasingly virtualizing, it is expected that future security concepts will be affected increasingly by personal security and data protection strategies. This may cause a shift from an outward looking offensive security strategy to a more inward looking defensive strategy. Consequently, future arms races may be replaced by approaches towards competition on access to information, flexible organization, and rapid deployment of forces in any place. Instead of being large and rigid organizations, armies may be organized as a cluster of smaller, flexible, self-sufficient, and mobile forces. The trend towards no-tolerance to the loss of human live is expected to increase the use of unmanned vehicles and drones, and in turn to carry out a considerable proportion of military activities on virtual platforms.

The trend towards a smaller and distributed military organization will bring together several challenges. For instance, coordination between forces will become more difficult. Hence, there will be a greater need for virtual communication networks with a more efficient use of the ICTs. Furthermore, the remote and distributed structure will bring challenges for logistic support, which may jeopardize the continuity of military operations. It is anticipated that new alternative and sustainable energy and life sources should be developed as a part of this emerging new military concept.

In this respect, the military personnel to be involved in future operations will require different qualifications than the present ones. There will be an increasing need towards a new profile for military personnel. The decreasing proximity of military operations to society will require the military personnel to be strong in social communication and networking skills. Increasingly virtual operations will bring the need for capability to use the ICTs systems at the headquarters and remotely during the operations on the field.

The overall technological development within this new concept may need to be oriented towards becoming more 'anticipatory' and 'preventive'. Therefore, it is expected that in military R&D a considerable emphasis will be given to the sensor technologies and tracking and tracing systems. The R&D activities on military weapons may be orientated to 'defuse' instead of 'defeat'. It should be continuously emphasized that the key strategy of the military operations is not to harm, but rather to protect civilians with enhanced care without the loss of lives. Deterrence in this context can mainly be achieved with 'precautionary' approaches. Detecting violence while it is at the planning phase will play a key role. It will be immensely useful to share the best practices in precautionary operations through the wider constituents of society, such as using the media as an instrument for psychological warfare, so that necessary social and political support would be provided for the viability of operations.

The amount of data and information stored and shared through the virtual world has been increasing dramatically. In an increasing number of cases, the virtual reality is overtaking the real lives of people and organizations. In parallel, electronic sources of data and information, social networks, and the whole virtual world is becoming an important component and even platform for future warfare. In this context, competence on 'Big Data Analytics' is becoming more and more crucial for civilian and military organizations in order to identify strong and weak signals of what may emerge in the future through the scanning of information and data with advanced artificial intelligence algorithms. This will enhance the aforementioned precautionary approach for operations with the intelligent anticipation of the weak signals of likely tensions to emerge and their prevention before they generate serious security risks. Consequently, it is expected that in concept-driven military R&D, the key focus areas will include high capacity data mining skills, software and equipment with solutions for data noise reduction, data cleansing, anticipatory network analysis systems, patent recognition algorithms,

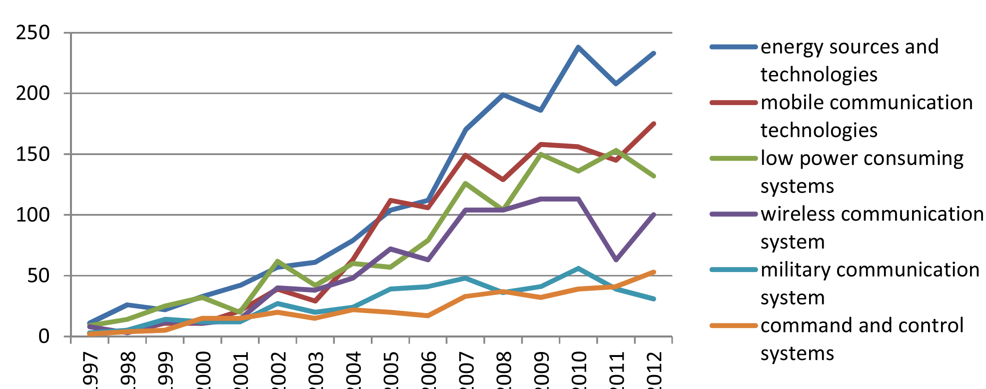

Fig. 6. Trends in the Energy and Communication Systems cluster.

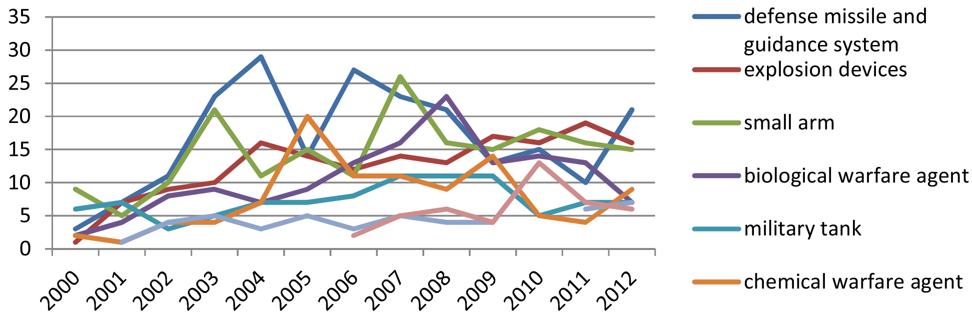

Fig. 7. Weapon Systems cluster.

sensors, advanced socio-technological studies, in addition to non-lethal weapon systems and alternative energy systems for the sustainability and prolongation of operations without interruption.

Following a discussion on how concept-driven approaches may shape military R&D and technology development, below, the paper will continue exploring possible implications of a technology-driven scenario on military R&D and future military concepts.

6.2. Technology-driven scenario

The patent analysis provides useful insights on the future trends and the ways in which emerging technologies may shape future military concepts. It is expected that most of the future military equipment from a single rifle to more sophisticated vehicles will be composed of a combination of 'imaging', 'identification' and 'tracking' systems through sensor and detection technologies; will be armed and armored, but unmanned; and will be aerial, all-terrain or a combination of them.

Long lasting operations will be implemented with the equipment powered by diverse and sustainable energy sources. The combination of ambient energy sources such as air, water, soil along with other natural energy sources such as sun and wind are expected to be among the key sources of energy. All military equipment is expected to communicate with each other through machine-to-machine communication systems, which will enable sharing real-time data, performing diagnostics, and making virtual repairs all without human intervention. Humans may be involved in the decision making process at a very final stage to give 'green' or 'red' signal to operations. An illustration of a possible convergence of military technologies and how they might work together in a war context is given in Fig. 9.

The figure illustrates a set of networked future technologies with new, renewable and ambient energy sources being at the heart, which was one of the emerging trends identified through the patent analysis.

The advancement of military technologies in this trajectory highlights the increasing need for new decision making systems based on artificial intelligence and networks, which may in turn radically change the whole structure of military organizations, military education and training systems, distribution of authority and responsibilities, and the nature of military operations and concepts overall. For instance, instead of a centralized system, a more distributed decision-making system, where decisions can be made locally and in real time and are monitored, evaluated and given feedback by a common intelligence system with the integration and synchronization of different land, air and navy forces, which may not be a very relevant division of forces in the future. New skills and qualifications will be needed to participate in military operations and to provide new services. In parallel to the converging military technologies, new military education and training systems will be designed to generate multi-skilled military personnel, for instance, to be able to operate drones, make decisions, and at the same time provide communication and logistical support. More distributed decision making and leadership will bring more widespread access to

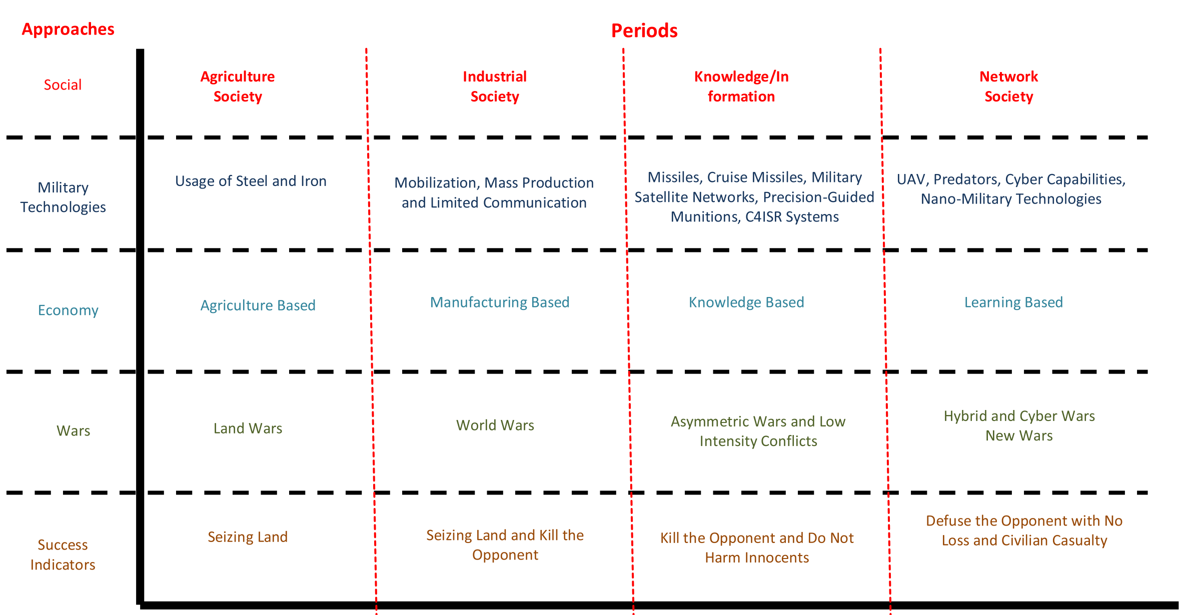

Fig. 8. Aggregation of findings in a graphical representation. Social approaches are not the focus of this study. Hence the authors tried to give general insight about social changes by using Bell's (1999), Walsh's (2013) and Castells and Cardoso's (2005) classifications and concepts for defining these general trends. It is not supposed to begin a new sociological discussion by using these words in this study.

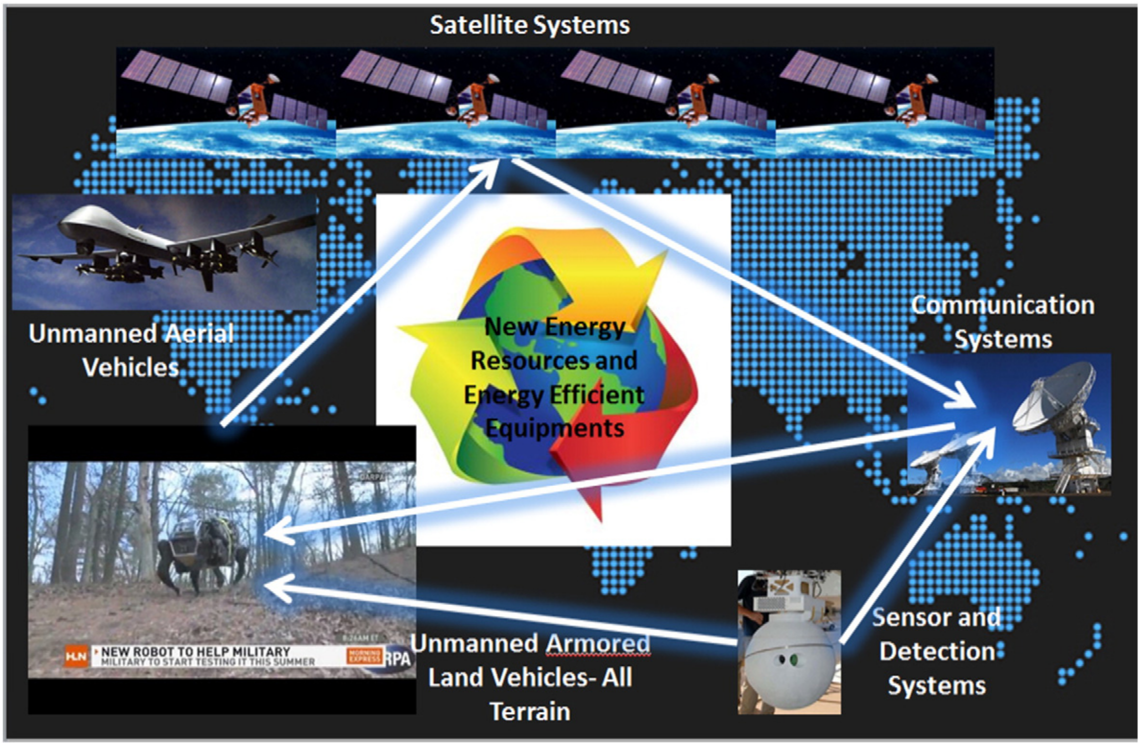

Fig. 9. Convergence of military technologies.

information by the military personnel and this will result with the dissolution of the top-down hierarchical structure of the military and the formation of more horizontal and flexible teams. *Re*-organization of armies with the widespread use of future technologies clearly gives the first signals of emerging RMAs.

7. Discussion and conclusions

In light of the discussion above, it may not be an overstatement to say that the armies are getting closer to a new RMA. Fundamental changes are being observed in the external contexts of warfare including Societies, Technologies, Economy, Environment, Politics and Values/Cultures (STEEPV). The emergence of learning societies enriched the diversity of lifestyles and levels of development in the world, and as a result increasing 'asymmetry' in the balance of powers. The use of increasing Information and Communication Technologies with an increasing information intensity of daily lives has generated various new opportunities. In parallel, the historical review and patent analysis have already given the 'weak signals' of a change in the meaning of military power, which is clearly shifting from the use of forces towards the use of information. In this respect warfare is becoming more focused on disobedient civilians than enemy armies of other countries. This will undoubtedly change the nature of military operations. The two scenarios presented above have described these changes from 'concept-driven' and 'technology-driven' perspectives with their implications on military R&D.

Among the points, the concept-driven scenario highlights are the changing nature of the battlefield, which is becoming largely virtual with a closer proximity to civilians and society; there is less tolerance for losses of human life; and more anticipatory and preventive operations with the aim moving to defuse rather than defeat. The technology-driven scenario emphasizes the common characteristics of future military equipment enhanced by ICTs, sensors and satellite systems; alternative energy sources for continuous operations; and big data analytical skills and capacity. Both scenarios discussed the implications of these developments on the new structure of armies towards more flexible, distributed, but network-type organizations supported by multi-skilled personnel. Both concepts and technologies will influence each other, and this military R&D, in certain ways. For instance, the key aim for preventing the loss of human lives in the concept-driven scenario may require the development of non-lethal weapon technologies. Similarly, the increasing use of ICTs move the military concept towards more networked organization and operation in smaller teams with distributed decision-making power.

It is concluded that the two scenarios presented above can be considered complementary rather than competing with each other. Future RMAs are expected to be co-shaped by both changes in military concepts and technologies. Therefore, the question at this point is not whether concepts or technologies will be the dominating drivers of this transformation process, but more what the meaning of 'power' will be for armies, and how this power will be organized with an innovative combination of military concepts and technologies. It is anticipated that knowledge-based, anticipatory and preventive concepts and enabling technologies for those concepts will form the backbone of future asymmetric warfare. Several concerns will need to be addressed in this process. For instance, continuous surveillance of the society online and offline brings to mind George Orwell's well-known novel "1984", which may raise concerns about 'privacy'. A fine balance will still be required when collecting information for intelligence while caring for the private lives of citizens.

When the transformations in military R&D are considered in the light of the aforementioned concept and technologies, it becomes clear that the distinction between military and civilian R&D is getting blurred. The close proximity of military operations and society is an influential factor on this trend. Hence, there are greater opportunities to design R&D programs and develop technologies with greater 'dual-use' potential. This synergy may provide more efficient use of R&D funding, infrastructure, and human capital. In this respect, energy is one of the most promising areas of research. There is an enormous overlap between society's and military's expectations towards alternative, sustainable and secure sources of energy.

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