Stefan Axberg

Tools of War – a Few Remarks on the Subject of Military-Technology

Today, in most western countries, we observe an ongoing transformation in the field of homeland security and homeland defence in order to develop new capabilities and structures of the armed forces. Some people have described the transformation as a revolution in military affairs, while others have a more moderate perspective on the development[1]. Common for most debaters is the impact of technology development as a key source for the transformation. Technologies in today's security systems are not military exclusive nor nationally unique as they used to be. This will change the way we develop and apply new technologies in the service of national and international defence. Both the physical and intellectual aspects of warfare are important for the ongoing change and development of the future armed forces[2]. It calls for better understanding of the meaning and role of technologies in future defence systems. One minor contribution in this respect is the ongoing development of a new academic subject – Military-Technology – in Sweden[3]. There is deliberately put a hyphen between the two words *military* and *technology* to emphasis that they are linked and that they now form one word, one term, having a different meaning than the two words standing separate. This will be elaborated later on in this paper.

War

War is fought between human beings, not between machines and is hence governed by human behaviour and different cultures. One could argue that war is a social activity and that the nature of war is always the same. However, the character of war changes all the time as technology to a large extent drives this process, technology being one of the most effective propellants of rapid development of military operations[4].

There are certainly various and numerous reasons for war and conflicts. Some fundamental ones are listed together with their rate of technology dependence in Table I.

Different views as religion, political ideologies etc is one reason quite often referred

1 See e.g. Cebrowski and Garstka 1998, Alberts et al 1999, Smith 2002, Fastabend 2005
2 Axberg 2006
3 Ibid.
4 Dupuy 1984

to – a modern example is the 9–11 event in USA. Looking back in history, there are endless examples. One is the nine medieval crusades during the 12th to 14th century[5]. Another example is the Thirty Years' war, which actually was a series of religious wars in central Europe lasting from 1618 to 1648[6].

Access to fresh water is more seldom discussed in this context, in spite of fresh water being of fundamental importance to individuals as well as to society. Having fresh water, human needs as health, hygiene and food can be met providing you have the basic technology for water management, like distribution and cleansing, together with a suitable infrastructure. However, there is a global shortage of fresh water. Slightly less than 0.8 % of all water on Earth is available and usable for biological life on land[7]. Fresh water is also unevenly distributed on the planet. In addition, there is a large difference how we use our water resources, e.g. in the developed countries, fresh water is to a large extent used for transportation of waste. Control of water distribution and technology for water management is a strong political and economical weapon today not fully appreciated, maybe with an exception for the Middle East conflict where it has been used for a long time[8].

Fundamental causes	Based on	Technology dependence
Different views	Religion, Ideology, Nationalism etc	Indirectly
Access to fresh water	Geospatial distribution, infrastructure,	Moderate to strong
Access to energy	Geospatial distribution of natural resources, technological know-how, infrastructure	Strong
Access to food	Access to water, energy, infrastructure etc.	Indirectly
Internal governmental problems	Various causes	Weak

Table I. Some high-level and simplified basic causes of war and their dependence on technology.

The access to energy – resources and technology – is also a basic cause of war which, in my opinion, might increase in importance. Securing near-future supply of petroleum derivatives for e.g. the United States, India, China and Pakistan might eventually lead to major crises. Control of exploration and distribution of these products is an effective weapon. The examples are numerous, not least from the last decades[9]. Energy infrastructure expansion to poorer, densely populated areas will eventually grow; however, it will not always have the intended effect[10]. One also has

5 Seward 2000, Armstrong 2001
6 See e.g. Parker 1997
7 Gleick 1996
8 Klare 2002
9 Ibid.
10 Pachauri et al 2003

to take into account that it takes 25–30 years to gain effect of a new or substantially changed energy policy[11].

The subject of Military-Technology

One can easily note that the meaning of military technology is quite different in different parts of the society and it varies a lot between countries. In Sweden we recently, in 2000, began to develop a new academic subject, Military-Technology, and we have now reached so far that we have a commonly accepted definition of the subject[12]:

Military technology is the science which describes and explains how technology influences military activity at all levels and how the profession of an officer affects and is affected by technology.

Military-Technology is based on several different subject areas from different disciplines and combines understanding of the military profession deriving from social science with the foundations of natural science and with a superstructure and dynamics supplied by engineering.

Military-Technology deals with matters which ultimately have to do with an officer's ability to carry out his profession. The officer must be able to use technology as a tool of war as technology by itself cannot solve any military problems [13].

If you compare research questions from traditional academic disciplines like Medical and Natural Sciences, Mathematics and Engineering with those of new academic subjects like Military-Technology, Command and Control and Operational Arts, one might observe that these latter subjects have research questions of not only fairly high complexity, but also contain a large amount of uncertainties. This is especially clear regarding optimization on arenas where the behaviour of the players is governed by non-linear equations. Regular laws must naturally, in the good spirit of Popper, be considered as hypotheses and be tested further against empirical evidence in a manner which at least makes it possible to reject the hypotheses if they fail to add up. The challenge is to assess risks and select the correct tools; however, maybe the most important is having the ability to reject the tool worst suited for the problem at hand.

11 T. Fransson (KTH) 2008, pers. comm.
12 Axberg, op. cit. , FHS 2007
13 Axberg 2002

A Military-Technology mindset

Both the physical and intellectual aspects of warfare are important for the ongoing change and development of the future armed forces. Impact of new technology and also technology as a tool must be considered along with doctrines and operational principles.

Having a Military-Technology mindset means that the officer knows of relevant Military-Technology methods, the impact of new technology and can use technology as a tool of war. This must be considered together and in conjunction with doctrines and operational principles in order to create incentives to act in a way that favours the operation etc at hand.

The understanding of Military-Technology issues by all officers is of decisive importance for the ongoing transformation of the Swedish Armed Forces. A network based future Swedish defence must, in my opinion, have leaders with a good knowledge of the possibilities and also the limitations of technology in combination with a fair general knowledge of modern and relevant technology.

To be able to balance detailed tactical/operational requirements against each other, a fair to good Military-Technology competence among all the staff officers is required. By using this competence it is possible, for instance, to assess the resulting military effect on a high-level system when changing the requirements on a subsystem like a sensor or a weapon. With Military-Technology competence commonly at hand, optimised and technically sound systems suitable for new tasks can most likely be defined and eventually obtained.

The technological systems to be used in network-based defence will to a large extent be based on knowledge acquired from technological demonstrators under "continuous" development, which will be assessed as allowing shorter lead times and application of the latest technology. This not only brings about advantages, but also, which is a serious matter, the fact that utilised technology seldom is tested in the intended application, which in turn imposes new strict demands on the officer's technical understanding and ability to see the link between the technology (in fact its usefulness) and tactics and operations. A particular problem in this connection is the development of Command and Control systems and methods for a Network Based Defence against a background of major information flows and the special validation problems which may arise in a varying cultural and societal framework.

Military sensemaking

The word sensemaking is used in different meanings and connections, originally being an organizational term.[14] It's nowadays often used within the Command and Control Science, constituting one of it's main functions[15]. Military-Technology forms, in my opinion, together with Operational Arts what one tentatively could call *military sensemaking*. This comprises not only an understanding of the traditional military theories, but also having a Military-Technology mindset with a fair to good knowledge of relevant tools. In order to obtain effective military operations all this must be present. No military operations can be performed without technical means, but technology *per se* does not contribute to military activities. Providing information to the officers regarding Military-Technology methods, e.g. systems engineering, optimization and probability calculus, may help them make sense of technology[16], thereby enabling successful military operations. Thus, one might say that the knowledge contained within the academic subject of Military-Technology is a prerequisite for performing successful military operations.

The tools

Man has always used tools to facilitate activities. Not least have tools been used for warfare purposes. Now and then in the history of warfare the first application of a new tool has given a decisive advantage[17].

There are intellectual and physical tools. Lanchester's equations, game theory and (military) standards are examples of the former, missiles systems, fighter aircrafts and sensor systems are examples of the latter.

The impact of technology is found at the lower tactical, tactical, operational and military strategic levels (nomenclature according to Swedish tradition). The impact seems to be more discernable at lower levels, e.g. when one or more of the enemy's technical systems is put out of action through interference, misleading information, etc, and the necessary tactical adaptation is carried out by using a combination of technological and tactical skills.

With a good knowledge of the tools, i.e. everything from weapons and platforms to information and management systems together with a Military-Technology mindset based on generic methods and theories relevant for waging war at different levels, the

---

14 Weick 1995
15 Brehmer 2008
16 Griffith 1999
17 van Creveld 1991

combat can be advanced successfully at all levels.

Of course, it's not the tools themselves that are important, it's the way you use them as stated earlier in conjunction with the Military-Technology definition.

Today, unlike earlier, military technology are not, with a few exceptions, leading the technology race. The civilian lead is clearly illustrated within the field of information technology. Nevertheless, this rapid development has obviously a large impact on military operational capability.

Disruptive events – Strategic dislocation

The impact of technology is increasing at strategic level, and is hence often linked to essential technological development stages[18]. There are several important "strategic dislocating" events in this matter; however, only a few examples from the last 50 years will be given here.

One well-known example is Trinity, the first nuclear weapon explosion on 16 July 1945, which was used three weeks later to bring about the end of the Second World War[19]. The Reagan Strategic Defense Initiative ("Star Wars") is another example of how new technology can be used for strategic purposes[20]. The control over the dissemination of information technology applied by the US can also be said to be of great strategic importance.

The launch of the Soviet satellite Sputnik on October 4 1957, followed one month later by the first animal in space (a dog named Laika) clearly illustrated that the US was behind the Soviet union regarding physical science. The since long ongoing debate regarding an educational reform in the US came into focus and funding for aggressive educational programmes were decided upon[21], thereby forming a base for today's advanced technological society. The first man in space, Yuri Gagarin on April 12 1961, led to the famous speech by president John F. Kennedy on May 25 1961, to "…before this decade is out, land a man on the Moon and bring him safely back to Earth..." On July 20 1969 this was achieved.

One of the most important innovations is, of course, the design of the transistor by Bell's Laboratories in the late 40's[22], for which John Bardeen, Walter Brattain and William Shockley shared the Nobel Prize in 1956. The semiconductor gave rise to several military important issues like miniaturization of weapons and field equipment,

18 Ibid.
19 See e.g. Jones 1985, Volkman 2002
20 Duric 2003
21 Divine 1993
22 Lojek 2007

increased portability and availability. The electronic and computing "revolution" that followed was initially a military concern, but soon the civilian demand dominated. This was especially clear regarding computers and processing capabilities, leading to in 1969 that several computers could work together using a standard, Network Control Protocol NCP, forming the military network ARPANET[23]. Applying a new addressing standard, the IP protocol, ARPANET in 1983 "became" Internet.

The 9–11 event have to be mentioned as it became the starting point where theories and doctrines of military activities and those of security in society become very close to each other.

On January 11 2007, a Chinese Anti-Satellite weapon (ASAT) destroyed an old Chinese satellite, FY-16, at an altitude of 850 km. A year later, US Navy demonstrated the same capability using a SM3 surface-to-air missile. Considerable efforts and amounts of money are spent by USA to place ASAT weapon in space. You no longer talk about Air superiority; you need both Air and Space superiority. To illustrate this, one could imagine a scenario in which several of the GPS (or Glossnas or Galileo) satellites are shot down or otherwise disabled. That would most likely bring severe problem into world-wide power and communications systems as well as chaos in the area of global transportation and that certain weapons would loose some of its precision. It could also affect the world's monetary systems with a severe financial crisis following as some money transfers between banks is dependent on very accurate timing signals derived from these satellites[24].

A quick comparison between two military operations a decade apart, Operation Desert Storm (ODS) and operation Iraqi Freedom (OIF), gives that certain operational improvements, mainly due to new tools and the understanding how to use them, can be observed[25].

Firstly, the improved precision and weapon's effect allowed for fewer, but more efficient forces – however at a considerably higher cost. Also quality of intelligence improved, being more accurate and delivered when needed. This affected in a positive way the timing and coordination of operations. In OIF also one achieved decision superiority by having the correct information delivered to the correct person in time. This contributed in the effort of generating a common situation picture.

Unfortunately, there are also several negative examples. One is the "blue on blue" near Basra, where lack of understanding of function and way of operation of a new identification system on the Challenger II tanks cost the lives of UK soldiers.

23 Norberg and O'Neill 1996
24 Carroll 2008
25 See e.g. Hiro 1992, Boyne 2003, Keegan 2004

Concluding remarks

In my opinion, there are five Military-Technology areas that need to be closely monitored within the scope of Military-Technology research, see Table II.

Firstly it's Space technology and the importance of knowledge and understanding its possibilities and limitations.[26] The growing demands for both mobility and everywhere access puts certain demands on telecommunications systems. Not all countries have their own satellites or access to either military or civilian ones, the latter mainly due to economical reasons. Therefore a great deal of attention has been drawn toward platforms able to operate in the stratosphere at between 15 and 25 km altitude. They are called High Altitude Long Endurance (HALE). One example is DARPA's ongoing project Vulture Five Year Flying Wing with an alleged endurance of 5 years, a total weight of 450 kg and an energy supply of 5 kW.

Focal area	Affects
Space technology	Communications, Intelligence, GIS
Autonomy	Risk reduction, Routine tasks, Platforms
Optimization	Efficiency, Risk assessment, Cost reduction
Systems Engineering	Non-observable system properties, Procurement
Military-Technology theory	Technology and operations, Military Sensemaking

Table II. Focal areas for Military-Technology research.

The use of autonomous systems increases, especially in the area between crises management and military operations and hence the area of robotics with questions like which subsystems can be allowed to be autonomous and what functions you want to have full control over. These questions are not easily answered and further research is needed before designing e.g. new decision (support) systems. With increased participation in international operations a need has arisen to use unmanned vehicles for high-risk assignments, in order to reduce, as far as possible, the risks for participating persons. The need for close interplay between technology and tactics/operations becomes especially clear here.

Although optimization theories may be complex and not easily understood, they need to be addressed at all military levels by the successful commander. By applying these theories one can considerably improve the over all efficiency of single systems as well as whole operations. Where the biggest advantage when applied to the latter is to avoid suboptimization, i.e. subsystems not supporting the "greater good",

26 See e.g. Handberg 2000

optimization often shows most potential when applied to multi-disciplinary systems. Through optimization a more accurate risk assessment can be obtained and the resources can be utilised in a cost effective way. One typical example is optimization of flight trajectories in order to avoid detection of surveillance systems[27].

The past decade has witnessed crucial changes in the development of complex military systems on a number of points. The civilian market, thanks to its volume, is now on the cutting edge of technological development in areas where military applications previously occupied that position. The results of military technical development are now able to be reused outside the military sector, especially in the area of public security. The demands for very rapid deliveries of both new and modified materiel to engaged units have increased. All of this gives rise to entirely new demands for technology and materiel supply in the armed forces. Complex military technical systems contain a large number of system components consisting of both hardware and software with high standards for system properties such as system security, information security, maintainability and modifiability. This type of system properties, which cannot be directly observed or measured, is referred to as non-observable system properties and has a significant impact on complex technical systems throughout their lifecycles, and is generally a major cost driving factor.

NDC has the responsibility to educate and train high-level officers within these important fields and about 10 officers graduate each year after a two and a half year advanced programme with emphasis on Military-Technology. We have recently changed the pedagogical focus of this programme from basic fact-learning into an interaction between technology and operations. Seminars, advanced literature studies as well as essay-writing are key-elements when we try to implement a Military-Technology mindset to our students.

Our goal is to deliver better officers to the armed forces, not pseudo-engineers!

27 Norsell 2005

References

Alberts, D., Gartska, J. and Stein, F. 1999: "Network Centric warfare, Developing and Leveraging Information Superiority." 2nd rev. ed. Washington: CCRP.

Armstrong, K. 2001: "Islam. A Short History." London: Phoenix Press.

Axberg, S. 2006: "Military Technology as Science." *In* Axberg, S. and Foghelin, J. (eds): Perspective on Military Technology. Stockholm: The Royal Swedish Academy of War Sciences.

Axberg, S. 2002: "Military Technology – A Multifaceted Operation." (*in Swedish*) Stockholm: KkrVA HoT 2002:4.

Berkowitz, B. 2003: "The new face of war. How war will be fought in the 21st century." New York: The Free Press.

Boyne, W. J. 2003: "Operation Iraqi Freedom." New York: Forge.

Brehmer, B. 2008: "Vad är ledningsvetenskap?" (*in Swedish*) Stockholm: KkrVA HoT 2008:1.

Carroll, J. 2008: "Results from a GPS Timing Criticality Assessment." Presentation at European Navigation Conference. Toulose: GNSS 2008.

Cebrowski, A. and Garstka, J. 1998: "Network-centric Warfare: Its Origin and Future." Annapolis: US Naval Institute, Proceedings 124:1.

van Creveld, M. 1991: "Technology and War. From 2000 B.C. to the Present." Revised and expanded ed. New York: The Free Press.

Divine, R. A. 1993: "The Sputnik Challenge." New York: Oxford University Press.

Dupuy, T. N. 1984: "The evolution of weapons and warfare." New York: Da Capo Press Inc.

Duric, M. 2003: "The Strategic Defence Initiative: US policy and the Soviet Union." Aldershot: Ashgate Publishing.

FHS. 2007: "Ämnesplan för Militärteknik 2007." (*in Swedish*) Stockholm: Försvarshögskolan.

Fastabend, D. A. 2005: "Transformation and Operational Art." *In* Mc Ivor, A. (ed.) : Rethinking the principles of war. Annapolis: US Naval Institute Press.

Gleick, P. H. 1996: "Water resources." *In* Schneider S. H. (ed.) : Encyclopaedia of Climate and Weather. New York: Oxford University Press.

Griffith, T. L. 1999: "Technology Features as Triggers for Sensemaking." The Academy of Management Review, Vol. 24, No. 3. New York: Academy of Management.

Handberg, R. 2000: "Seeking new world vistas: the militarization of space." Westport: Praeger.

Hiro, D. 1992: "Desert Shield to Desert Storm: The Second Gulf War." New York: Routledge.

Jones, V. C. 1985: "Manhattan: The Army and the Atomic Bomb." Washington: U.S. Army Center of Military History.

Keegan, J. 2004: "The Iraq War." London: Hutchinson.

Klare, M.T. 2002: "Resource Wars. The new landscape of global conflict." New York: Henry Holt.

Lojek, B. 2007: "History of Semiconductor Engineering." Berlin: Springer.

Norberg, A. and O'Neill, J. E. 1996: "Transforming Computer Technology: Information Processing for the Pentagon, 1962–1982." Baltimore: Johns Hopkins Univ. Press.

Norsell, M. 2005: "Multistage Trajectory Optimization with Radar Range Constraints." AIAA Journal of Aircraft, Vol. 42, No 4.

Pachauri, S. and Spreng, D. 2003: "Energy and energy access in relation to poverty." CEPE Working Paper Nr 25. Zürich: Swiss Federal Institutes of Technology.

Parker, G. (ed.) 1997: "The Thirty Years' War." 2nd ed. New York: Routledge.

Seward, D. 2000: "The Monks of War." 2nd revised edition. London: The Folio Society.

Smith, E. A. 2002: "Effects Based Operation: Applying Network Centric Warfare in Peace, Crisis and War." Washington: CCRP.

Weick, K. E. 1995: "Sensemaking in Organizations." Thousands Oaks: SAGE Publications.

Volkman, E., 2002: "Sciences goes to war. The Search for the Ultimate Weapon, from Greek Fire to Star Wars." New York: John Wiley & Sons.