The complexity of weapon systems

Modern weapons continuously increase in complexity. In Afghanistan, almost 85% of the bombs used were guided compared to only 10% during the Gulf War. In order to answer a multiform and moving threat within a very constrained budget context, the weapon systems, and especially those developed in Europe, are resulting from numerous complex factors. Therefore they require a global approach, as when strategy is dealing with great military, economical or political issues.

Before going further it is important to define some terms. The system can be defined as a gathering of elements, each of them having a specific function and whose combination, following one process, is aimed at carrying out a mission. The complexity is to be understood as the degree of uncertainty and risk which is intrinsically linked to the system or to its development manufacturing.
This article will try to draw a picture of the substance of this complexity in order to better examine the means, as a military, to grasp its consequences and thus to succeed in integrating weapon systems.

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Systems which are necessarily complex

Despite the ever increasing possibilities offered by science, weapon systems still have a significant level of complexity. Two main reasons exist for this. The first one is related to the joint and multinational nature of engagements and the second one to the necessity, for companies, to permanently innovate in the field of weapons.

Current operations are essentially carried out within a joint framework, and often within a coalition, within or a UN or NATO framework.

Consequently, weapons systems must be adapted to this fact. For example it must be possible to integrate a ground-to-air device to other equivalent allied systems without forgetting the complementary ground-to-air systems. This system has to take into account air movements, and of course the threat under all its forms. All of this entails a very high degree of coordination that is ensured by interfaces able to dialog with all participants on the theater. In addition, it should be noted that the multiplicity of procedures, but also the very cultures of each country, add an additional layer to this complexity.
On top of this picture come the effects of the ruthless commercial war conducted by the armament world companies. It is legitimate to wonder why companies innovate. Why a more simple system should not meet the operational requirements when considering the average level of the threat ? One can recall that the strategy of the former Soviet Empire was aiming at destroying the opponent by saturating its defenses thanks to the employment of an enormous mass of equipment and that the manufacturing simplicity was the sine qua non condition for success. Today, for our companies, the deal is different. Innovation is an integrant part of their strategy and their dynamism in this area conditions their good health. They must anticipate on tomorrow technologies and integrate them at low costs. In this way the matter is to make weapon systems as resistant as possible to obsolescence. Therefore, and we should not be wrong about this, this ruthless competition requires, from the part of industrials, to develop the mostly technologically advanced systems able to

" The Army down to the more modest of its members, is subject to the law of progress with which any improvement that increases the power of men, in fact multiplie increases their labour. "

Général de Gaulle - Towards professional Army, 1934

compete with equivalent products, notably American, on all aspects.

Adapting to the constraints of modern warfare combat and competing with other products available on the market are the essence of the challenge that has to be accepted by weapon systems. Today, if technology is progressing rapidly, the threat and the economical conditions have also shown their capability to change quickly. It is in that context rather difficult to apprehend that weapon systems have now to be developed.

The development of weapon systems, a complexity factor

From the arrival of the first tanks during WW[1], to the blitz breakthrough of the Panzer divisions in May 1940, three decades were necessary to the definition of the weapon system that is represented by the tank. One can vaguely have the feeling that, despite tremendous progress of science and of the capital represented by years of military thinking, the arrival of a new weapon system is not the result of a natural process. If today budget constraints issues are added on top of this, this entails that often weapon systems have to meet, in a Cornelian scenario, very strong requirements in terms of performances and low cost development. Therefore, a great number of modern weapon systems have a complex development, and this mainly for industrial process, delays, costs, technology and performance reasons.

The complexity reasons are first linked to the industrial processes to be implemented. It is rather obvious that the days of a purely national industry are over. At the same time, it seems that no area should be left aside a priori, as this would be a loss of autonomy. Therefore, programs are often conducted within an international cooperation context in which all participants scrupulously look after the fulfillment of expected benefits. The industrial arrangements necessary for the conduct of programs are thus difficult to set up. These arrangements often generate extra costs that sometimes "oppose" generally accepted ideas about the advantages to work in cooperation.

In a second step, questions about time lines and time limits are extremely sensitive. It is recognized that during the very first steps of a program, which correspond to the definition, quite 70% of the costs are committed. It is therefore easy to understand the effects of successive programs' adjustments or the ones of equipment specifications' modifications, even the apparently insignificant ones.

Thirdly, the product in itself contains a part of risk, which is the result of the compromise between the selected technology, the performances and the accepted costs. This is strongly linked to the long development turnaround time that impose to cope with emerging technologies likely to reach a sufficient maturity level at manufacturing time.

Progress in component miniaturization is often a good example of this, when it is the case of lodging powerful calculators into the limited space offered by a missile body. Program contractors in a program know very well the share part of the benefits expected from a successful projection as well a the accepted very high risks they take on the contrary.

The management of all these factors requires a permanent strictness at all levels. The notion of compromise is omnipresent and is essential in order to achieve integrating the adequate weapon system at the appropriate time. For example, no one envisages the fielding of new infantrymen equipments without seeing, in the same time, the arrival of corresponding communication systems. Undoubtedly, mastering this complexity is a real struggle that presupposes to master time for a sound use of budgets in a correct manner. This requires from executives some responsibility commitments that are not deprived of risks.

Taking the necessary decisions is a great responsibility in which military participate. And this rightfully, as man continues to be at the center of systems generating an extra layer of complexity which should be apprehended at best.

Taking into account the human factor

The average technological level, which has significantly been increased, has partly led to

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the professionalization of armies, i.e. a reduction in strength. This new organization must allow to have fully competent and available personnel during enough time to make profitable often long and costly training education. If education followed by a regular training are the sine qua non conditions to efficiently set up and implement weapon systems, considering the ergonomics issue related to equipment hais also a very important aspect.

Efforts have been accomplished on the part called man-machine interface. This interface is the part of the system where man intervenes in any way. It can be a monitoring screen or a joystick. The efficiency of the weapon system is often dependent upon the quality of this interface. The general public computer systems are the best example of progress made in this field. Today, most of the software are very accessible as designers paid lot of attention to make their products very " friendly ". For a weapon system, all the combat conditions are coming on top of the difficulties pertaining to its implementation. Stress, cold, tiredness are as many additional handicaps. Therefore it is essential to adapt the weapon system to human factors by maximizing comfort and friendliness possibilities.

This adaptation presupposes a good knowledge of manhood, of his physical, physiological, psychical characteristics as well as of his culture. Therefore, it is necessary to have a real human model. Man is then considered as a system as such, whose behaviorism laws must be defined. For example, it has been noticed that, in front of a screen or an image bearing no particular information, a priori specific, and on which however a research must be carried out, the human eye comes back to a reading reflex. In this way, we would tend towards starting to search on the top left part of the screen whilst an Arabist would start on the top right part of it. Some weapon systems require going even further in that study. This is the case with systems that are called with man in the loop. Optical fiber guided missiles offering targeting facility designation at the right time by an operator who, on a screen, completely monitors the missile flight, are a perfect example of that case. Beyond the best inclusion of the human-machine interface, the difficulty for militaries, in this case, is to define, thanks to a doctrine, the limits and the interactions between the operator and his external environment.

Knowing that the operator will sometimes only have one fraction of second to designate the target to the missile, the results and consequences of the fire will not always be guaranteed. The global approach of such a system requires to include the political dimension of the fire as well as the emotional reactions of the operator. The complexity can therefore be easily understood.
Man definitely remains at the center of the weapon system. But recent evolutions show that he will always have to react with an utmost speed and a great accuracy. The interweaving of armies and of their weapon systems on the battlefield will become more and more complex to manage and this really shows the relevance of studies dealing with the human-machine interface part.

Mastering complexity is a major challenge for militaries who have stressed this point many times. Facing new types of operations since the fall of the Berlin Wall, they have perceived very quickly its necessity. The other determining factor when considering complexity is the general downsizing of budgets devoted to defense. If the perspective of an escalation up to the extremes, described by Clausewitz is somewhat fading, the threat is omnipresent and recent conflicts, especially the future ones those, show that defense cannot be missing a certain level of financing. In particular this level must make possible to ensure the reliability of systems in order to offer the expected operational availability.

The best use of budgets goes through mastering the complexity of weapon systems. It is the case of sizing their financial impact at best, which in particular imposes a cost approach over the whole lifetime and not considering only the purchase cost. To reach this mastery it is essential to use databases that are becoming, among others, through the use of statistical tools, the lights of the past in order to shed light on the future.

In a second stage, it seems important to scrupulously act within the long-term directives that are given in terms of defense while favoring a top down approach. These ones will indeed permit to determine the interfaces that should fit weapon systems in order to be integrated, in the best harmonious way, within the defense global system. To these ends, we should take care of the national aspect as well as of the international one, which is the preferential framework of all major operations. Therefore, the fact of taking into account weapon systems in their global nature would be devoted to meta systems i.e. systems of systems. Absolutely essential, these meta systems would come to federate all weapon systems in order to optimize intelligence coming from them and to rapidly deliver deliver, with a great accuracy, the fires necessary to the success of the mission.

A politically united Europe will there find a wonderland to express its role in the field of common security and defense.