Military Technology Is a Science of Artifacts

by Eva Jensen

Resumé

Militärteknik som akademisk disciplin studerar tillämpningar av teknik för militära syften. Syftet med denna text är att diskutera vad militärteknik är för slags vetenskap. Den inleds med en diskussion kring lämpligheten av att kategorisera militärteknik som en designvetenskap, på samma sätt som Brehmer kategoriserat ledningsvetenskap. Den mynnar ut i slutsatsen att designvetenskap inte täcker alla aspekter av militärteknik, vilket däremot den bredare kategorin vetenskaper om artefakter gör. Slutligen presenteras kraven på teorier och empiriska studier inom en vetenskap om artefakter och hur dessa kan appliceras på militärteknik. Militärteknikens uppgift är att studera hur de militära funktioner (eller förmågor) som är nödvändiga för att åstadkomma militära effekter kan utföras av eller med hjälp av teknik.

MILITARY TECHNOLOGY AS an academic discipline is concerned with the application of technology for military purposes. More specifically, it studies the military uses of technology from two different perspectives. The first perspective concerns how the military activity is affected by the introduction of new technology. The central question here is: What new capabilities does this new technology offer to the military or to the opponent? The second perspective focuses on how new demands on the military create new demands for technological solutions, and what kinds of technological solutions that might meet these demands.[1] Thus, it focuses on how devices of various kinds are invented and used in order to achieve certain (military) goals. This makes military technology one of the design sciences, according to the latest contribution in the series of textbooks on military technology produced by the Swedish National Defence College.[2]

The purpose of this text is to discuss the appropriateness of categorizing military technology as a design science. I will argue that military technology belongs to the broader category that we could call the sciences of artifacts (or the sciences of the artificial, in the words of Simon),[3] and in this paper I will present the demands on theory and empirical work in a science of artifacts and how they apply to military technology.

The analysis presented here is much inspired by the work by Brehmer[4] on defining and describing command and control (C2) science as a design science.

What is a Design Science?

Design sciences are included in what Simon[5] refers to as the sciences of the artificial. Simon contrasts the sciences of the artificial with the natural sciences. The natural sciences aim at understanding and explaining the "natural" world, i.e. that which has not been tampered with by humans. Human beings are ingenious creatures, however, who strive to improve on

their conditions. People invent and create. These creations are called artifacts.

An artifact is something that is man-made. It would not exist unless someone made it. Artifacts are not necessarily objects; a work procedure, for instance, is also an example of an artifact.

A design science studies the creation of artifacts; the process and the resulting products. Focusing on how things ought to be, and devising new instruments, or artifacts, in order to attain this, is the professional realm of engineering and design. Engineers are not the only professional designers, however. New medical treatments or new administrative procedures are also products of design.[6] This is also true of military forces and even military missions.[7]

People construct artifacts in order to facilitate the attainment of goals they pursue. A user wields an artifact in an environment he or she wishes to affect. This environment is called the *outer system*. The user and the artifact together make up the *inner system*. The user uses the artifact to fulfil some purpose or adapt to a goal in the outer system. The artifact is used to influence – to communicate with – the outer system, and may thus be thought of as an *interface* between the user and the outer system.[8]

When searching for literature on design research and design science, Tehler and Brehmer[9] found work that discussed the design *process*,[10] or how to find rules or recommendations for successful design, i.e. focusing on the *product*.[11] Tehler and Brehmer[12] did not, however, find in this literature any *framework* that could be used to understand and construct the artifacts that Simon[13] claims we need. For that we have to turn to textbooks on engineering design.[14] According to Brehmer[15] all such frameworks have to apply, in one way or other, what he has termed as the logic of design.

The Logic of Design

The first step in a design process is to identify the *purpose* of the artifact to be constructed. Why is it needed? What problem is it supposed to help solve?

Once the purpose is clear, it has to be sorted out what the artifact needs to accomplish in order to fulfil the purpose. This is a question of identifying the requisite *functions*. The functional description does not suggest a solution; it only describes what functionality is required for a solution to be feasible.

The possible solutions that would fulfil these functions are the alternative *forms* that the designer can choose to implement in the final artifact.

A function may be depicted as a box. We do not know what is in the box, but it is labelled with what it accomplishes. In the example in Figure 1, we want it to split an object in two. The input to the function is the object to be split, and the output is two separate objects, i.e. the parts separated by the split. As mentioned above, a function is defined by its output. The output in this case is an object that has been split into two objects, and the function (the label on the box) is to split an object in two. Nothing is said about how this is supposed to be done. That is defined at the next level, the level of form.

Splitting an object in two can be done in several ways. It might be cut with scissors, sawed apart, or chopped with an axe. These are possible *form* alternatives that might be chosen to fulfil the function of splitting an object in two (Fig. 1). Which alternative is the most appropriate depends on the material of the object in question.

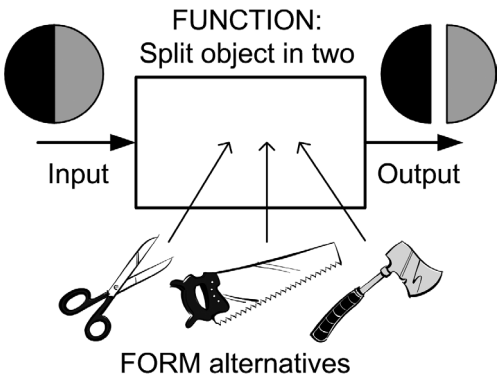

Figure 1. Alternative forms that could fulfill the function of splitting an object in two.

Defining the function of splitting allows us to discuss splitting in general, i.e. to formulate a general theory of splitting. It also enables us to compare and discuss splitting under different conditions in various contexts within the same framework. We can, for example, study the output produced by one form under different conditions (i.e. varying the material of the object to be split). We can also study the output produced by different form alternatives under identical conditions (i.e. trying different tools or methods to split identical objects). These are all studies of the phenomenon of splitting. Theoretical models expressed in terms of functions allow us to treat different solutions to similar problems within one common framework. Theoretical models at the level of form, i.e. of specific instances, such as scissors in our example above, are limited to such instances. A theory of scissors applies only to scissors; it does not apply to axes, or saws, while a theory of cutting applies to them all.

From this, we conclude that to achieve generality, theories in military technology should be formulated in terms of functions, i.e., they should be concerned with the functions that the military artifacts fulfil and not only with the artifacts as such. For this, we need to identify the functions in the military system that the military technology should contribute towards fulfilling. We now turn to this problem.

Military Technology as a Design Science

The Functions of Military Systems

The purpose of a military system is to bring about, or have the potential to bring about certain (military) effects. In that respect, military science, or war studies, also belongs to the design sciences.[16] Suggesting the requisite functions for successful military missions is a matter of military theory. I am not aware of any theoretical models of military systems expressed in functions, however, but the required capabilities listed in Swedish doctrines cover quite nicely, I think, the functions generally required in military endeavours. One of these functions is, just as noted by Jenkins et al.,[17] to deliver the desired *effects*. What effects that are desired will, of course, differ from mission to mission. Additional capabilities are a need for *movement*, for *protection*, for *endurance*, for *intelligence*, and for *C2*.[18] As the functions constitute a theory of what military endeavours require for being successful they also provide a means for understanding why the level of achievement turns out to be what it is: it depends on the extent to which the functions listed here are fulfilled.

Defining Requirements

The functions are defined by their output, i.e. by what they accomplish. Taking the function of protection as an example, there are several things one might wish to

be protected from. Hostile fire is one such thing, the weather is another. If we concentrate on the weather, you would typically wish for protection from heat, cold, wind and rain. The question is how much protection you want. What are the performance requirements? What range of temperature is acceptable to the entity that is to be protected? The task for the protection function is then to keep the temperature within this range; the smaller the range the higher the demands on the protection.

What output is required and how difficult it is to achieve depends on the context in which the artifact is to be applied, i.e. the outer system in question. Protecting from cold weather is somewhat more challenging in the Arctic areas than in Mediterranean areas, for example. To ascertain these performance requirements is an important task for military technology as is assessing the extent to which different forms of equipment can live up to the relevant performance requirements.

The performance requirements and the context are not the only factors that put demands on the envisioned artifact. There are also other factors that constrain the range of acceptable solutions (form alternatives).[19] One of these factors is cost. What is the maximum acceptable cost? There may be laws and regulations that have to be followed. The prospective users will also constrain the possible solutions. What can they be expected to be able to deal with, and what will they accept? These are just two obvious examples. There may be other constraining factors as well. Together, these factors specify the requirements on the artifact, be it something designed for military or civilian use.

The logic of design is well suited for analysing the demands on technological solutions to satisfy new requirements on the military, and to evaluate the extent to which suggested solutions meet these demands. The focus is on specific problems that need to be solved, i.e. whether or not the purpose is clearly defined. This is the case for command and control systems, and the study of such system, i.e. command and control science, therefore belong to the design sciences.[20] If we limit military technology to studies of the military uses of technology from the second perspective mentioned in the Introduction, then military technology would also be a design science. However, we have the first perspective as well, i.e. how new technology may affect the military, which is not covered by what has been presented this far.

Using Artifacts for New Purposes

An analysis of an artifact within the design framework is done with a specific purpose in mind. The creation of a new artifact that will fulfil this purpose is considered, or, in the case of evaluation, the ability of an existing artifact to fulfil the purpose. An artifact may, however, be applied to fulfil other purposes than the one it was originally made for. Computers come to mind here as the ultimate example of this. Who could have forecasted that an artifact developed for aiding the solving of problems in ballistics would in the end be our principal means of communication on the battlefield and elsewhere? An analysis of such possibilities could be said to follow the logic of use. It looks much like the logic of design turned upside-down.

The Logic of Use

If the logic of design is applied to *one purpose*, the logic of use is applied to *one artifact*, i.e. one specific form. I will illustrate this logic with a brick. Consider a brick and

think of as many ways as possible where you might use it. While there is a limited set of functions that are necessary and sufficient for fulfilling a specific purpose within a given set of constraints, the number of functions that might be fulfilled for various purposes by a given artifact is mainly limited by a prospective user's aptitude for divergent thinking.[21] Figure 2 shows only two possible functions that the brick may provide. It may support a wobbly table or books on a shelf, for example. It may also serve as a weight, to keep papers in place on a desk, or as a weight on a balance scale (if the mass of the brick is known).

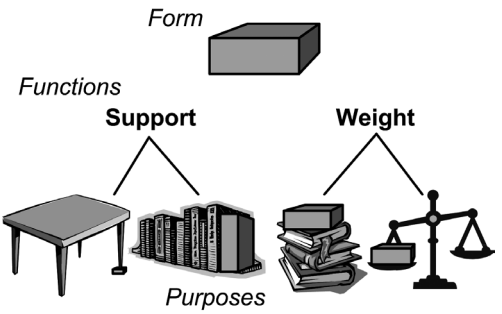

Figure 2. Possible purposes and functions of the use of a brick.

The capabilities or functions provided or enabled by new (or old) artifacts, and the possible purposes they might fulfil can be analysed by applying the logic of use. This can be done both from the perspective of the military and from the perspective of possible opponents. The military system offers a wide range of examples of artifacts developed for one purpose and then used for another militarily, such as spades being used as weapons.

According to Simon,[22] the sciences of the artificial study *both* the creation *and* application of artifacts. I therefore claim that military technology is a science of artifacts and not just a design science.

Theoretical and Empirical Military Science

A general theory of how military effects are achieved should, as mentioned above, describe what functions are required, but also how these functions are related, i.e. the functional structure of a military system. Moreover, the theory should specify what output is required from the functions under what conditions in order to (be likely to) achieve a certain outcome.

Such a theory can then be tested by designing systems (or artifacts) that perform as specified under the given conditions, and observe if they produce the expected outcome; and, if systems that fail to meet the specifications do not. To readers who would like to read about this in greater detail, and who read Swedish, I recommend Brehmer's book on command and control science.[23]

Military Technology

A theory within the field of military technology should explain how a certain type of technology would either contribute to one or more of the military functions or what demands it would put on these functions, depending on the context and the purpose for which it is applied.

Simon[24] criticizes professional schools for focusing almost exclusively on the natural sciences at the expense of design. Engineering students are taught a lot of mathematics and physics, but very little actual design. The situation has improved somewhat since Simon first published his book,[25] but there are still rather few courses offered on design in the education and training of engineers. Research at engineer-

ing schools is likewise mainly done in the natural sciences, and, these days, in the computer sciences. In fact, modern systems engineering is much inspired by the practices of software engineering. Computer and information science may be credited for bringing design and engineering back into the education and training of engineers.

I wish to stress that the task for military technology is not to study the technology used by the military as such. Neither is the actual construction of the artifacts an object of study for military technology. The focus is on the *purposeful use* of technology by the military.

Theories of how some form of technology contributes to the military functions can be tested empirically by testing if a solution employing the technology in an appropriate way produces the expected performance in the given context.

Theories of what demands the introduction of new technology that may be used by an adversary, or otherwise affect the context of military actions, will make on the output from the military functions can be tested by comparing the performance of military systems in a context with this technology with the performance of identical military systems in a context without it, with all other factors being equal.

Hence military technology as a science of artifacts is both a theoretical and an empirical enterprise with a need both for theory of developing and explaining military artifacts and formulating the requirements that they should meet and for methods of testing whether the designs that are developed fulfil the various military functions and for measuring the extent to which they do so. In summary, the task for military technology is to find technology (in a broader sense) that helps the military fulfil the functions that are necessary for achieving military effects.

The author is employed by the Swedish National Defence College, holds a PhD in Psychology and a MSc in Electrical Engineering.

Notes

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