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C2 HUMAN FACTORS ENGINEERING

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EVALUATION OF HUMAN PERSPECTIVES IN SYSTEMS OF SYSTEMS: A CHALLENGE OF THE FUTURE MODELING AND SIMULATIONS DEVELOPMENT

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ABSTRACT

In this paper, we will discuss the problems of evaluating systems-of-systems from a human-centric approach by describing the start of a suggested methodology for such an evaluation. The work is an attempt to evaluate the work in the Swedish Armed Forces Transformation Program and Command and Control Development. It is our belief that the basis for human evaluation in systems-of-systems in many ways is the same for all future modeling and simulations development, rather than specific for the Armed Forces. By creating relevant methodology frameworks for evaluating human perspectives in systems-of-systems in the development, we will be able to test a transformation from today's techno-centric approaches to a more balanced techno-human. For this, we need to balance the technical approach with the human-centric approach. In this paper, we will discuss some key issues of such a methodology - framework development. The work has just begun and our argument should be considered as a starting-point for requiring further refinement. In this presentation, we focus on the issues of: a) the network environment, b) what constitutes systems-of-systems, c) how do we know that we know? and d) taking sociograms to the next level by using the concept of potentials.

IMPORTANT NOTES: This paper contains facts and opinions, which the author alone considered appropriate and correct for the subject. It does not necessarily reflect the policy or the opinion of any agency, including the Government of Sweden, Swedish National Defence College or Swedish Defence Research Agency.

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Introduction

In the mid 1990s Murray presented a number of case studies from the 1920s and 1930s regarding innovation. He argues for the idea that this time period has great similarities with the situations of today. One of his conclusions is that human behaviors are so complex that they are literally unpredictable or chaotic.[1] He also concludes that culture is perhaps the most crucial factor for innovation success. His thinking may have some implications for how the evaluation of the human perspectives within the Swedish Armed Forces transformation program and command and control development should be designed in order to balance the technical- and human centric approaches. Will humans fulfill the requirements of future combat systems? Today we lack a consistent methodology for evaluation of technical systems-of-systems.[2] The mainstream military literature today covers many central parts of such methodology,[3] but an overall methodology for systems-of-systems in which humans are involved has still to be developed. In this paper, we will supplement the view of the main-stream military literature by discussing the problems of evaluating systems-of-systems from a human perspective, and by describing the start of a suggested methodology for such an evaluation. The work is funded by the Swedish Armed Forces Headquarters and is an attempt to evaluate the "demonstrators" work in the Armed Forces Transformation Program and Command and Control Development. It is our belief that the basis for human evaluation in systems-of-systems in many ways is the same for all future modeling and simulations development, rather than specific for the Armed Forces Transformation Program. By creating relevant methodology frameworks for evaluating human perspectives in systems-of-systems in the modeling and simulation development, we will be able to discuss and test a transformation from today's techno-centric approaches to a more balanced techno-human one. In order to evaluate systems-of-systems we need to balance the technical approach with the human-centric approach. In this text, we will discuss some key issues of such a methodology - framework development. This work has just begun and our argument should be considered as a starting-point requiring further refinement. In this presentation, we will discuss some important issues including: a) the network environment, b) what constitutes systems-of-systems, c) how do we know that we know? d) taking the concept of sociograms to the next level, and e) some final remarks.

The Network Environment

At first we need to consider the network environment. The military threat has changed, and with that the military forces need to adapt to the new challenges. In Sweden, the transformation program is named the Network Based Defence (NBD).[4] The transformations of the armed forces of most western countries are described as based on systems-of-systems, although we still have some confusion about what that term means.

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[1] Murray (1996:p 24)

[2] Admiral Owen revived the term 'systems of systems' in the book *Lifting the fog of war* (2000). In 1999 Annette Krygiel had explored describing an integration environment for system of systems, and today the term system-of-systems of one of the buzzwords for the transformation.

[3] For examples see NATO Research and Technology Organization (RTO), "*NATO Code of best practice for C2 assessment*," 2002, or David Alberts and Richard Hayes (2002), two parallel works that give an overview of the state of the art today.

[4] For a more extended description see Friman (2003)

Before we can start to evaluate anything at all, we need to define the objectives for our evaluation.

In future military missions, the personnel will meet different types and degrees of uncertainty, and therefore future military organizations will need to be more flexible. In order to create flexibility in the organization more attention to the different forms of networks will be needed. It will also be necessary to pay more attention to the relations between entities within those networks and to the relations between entities in different networks. Networks are about relationships that form the nets rather the specific components.

In a recent case study of joint combat, we identified three networks of specific interest for future military organizations: a technical, an organizational and a social one.[5] The network environment in this sense means that systems-of-systems can be described as technical and human centric networks, with the organizational layer in between.

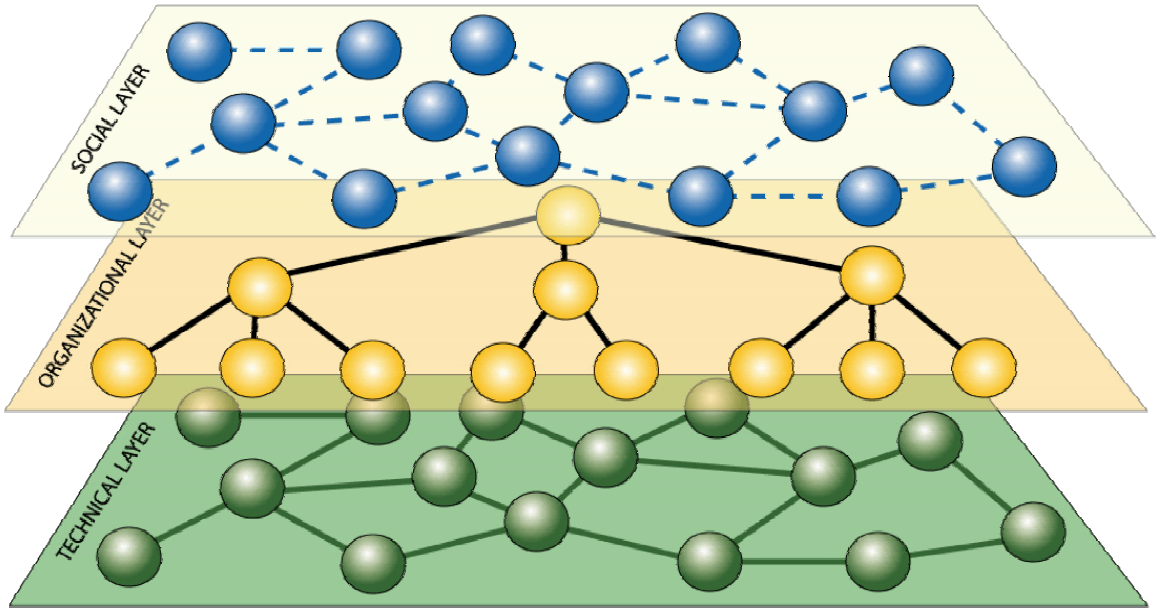

Illustration of the three key networks

As a pertinent result, we observed that the social and the technical networks could be designed with looser connections and may be more freely set up on demand than the organizational network. This is in agreement with the fact that military organizations in particular are hierarchies and take time to establish to function efficiently. These organizations are in the best cases direct reflections of the activities that they intend to fulfill. For such important activities as combat activities we need to be strict on how we give authority to use weapons. An important question for the future is therefore whether

[5] Swedish National Defence College (2003)

only an organizational network will be accepted for military activities including the use of lethal force?

The development of NBD is an ongoing process and much more work needs to be done before we can say that we have the solutions to function efficiently in future military environments. In this paper we restrict our discussion to just the social layer or the *social network* and we will regard it as a system. Using this approach gives us a theoretical basis for a multidisciplinary approach to bridge the gap between the scientific approaches used in various technical disciplines and the approaches used in cognitive, neural, and social sciences. In the latter disciplines we will find system approaches, which provide possibilities for theory development and descriptions of systems-of-systems. We hope by this to bridge the gap between the technical- and human-centric approaches, and to create a broader understanding for the human perspectives in the techno-centric community of system developers by creating a pedagogic link to human-centric approaches.

What constitutes systems-of-systems

The term systems-of-systems (SoS) generates in most readers a number of associations. We like to describe SoS as a number of related components which together create higher level effects then if they were used alone.[6] The reason for integrating systems is mainly to create enhanced effects. One example of this is Murray's description of military culture as: *"One might define military culture as the sum of intellectual, professional, and traditional values possessed by an officer corps."*[7] Three important perspectives may be applied to describe what constitutes a SoS. These perspectives all involve human and technical aspects and emphasize that we need a balance between the technical- and human-centric approaches for a successful Armed Forces transformation program and command and control development.

Optimizations of performance versus balancing of performance. A SoS can be categorized by the foundation of the system, be it technical or human. A pure technical SoS can be when two different technical systems are connected together, or a purely human SoS can be when human groups are interrelated in social systems. Technical and human scientists have studied these two kinds of SoS separately for many years. However, in realty and in the military we find SoS that are mixed technical and human systems and that are even more complex to describe, understand, and evaluate than either of them alone. For the transformation, we need to apply knowledge from both domains,

Effects in technical systems are often described as *optimizations of performance*, which is a trade off between quality, quantity and cost aspects. From operational research officers we have learned to optimize processes based on quantitative data and statistical analyses. The baseline for achieving such data is that the systems are well defined, and that the components have recurrent functions.[8]

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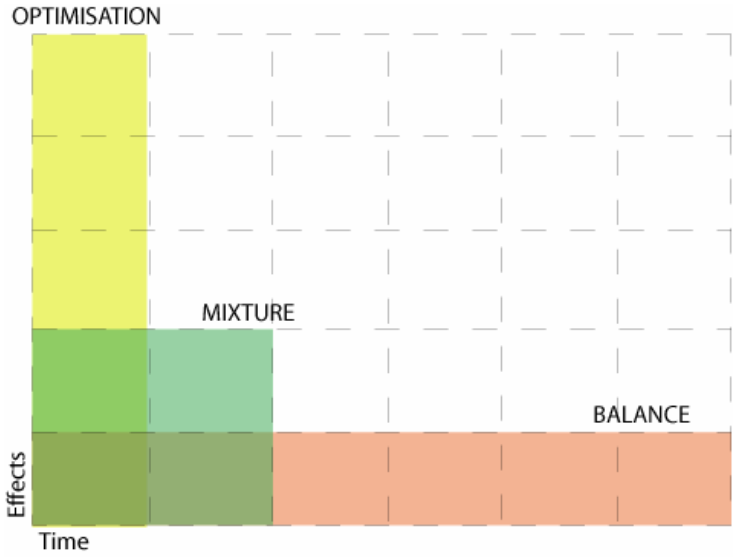
[6] van Gigch (2003)
[7] Murray (1996:p 26)
[8] E.g. Albert and Hayes 2003:44f arguments on optimization.

Effects of human systems in military contexts are more often described in terms of survival, which rather concerns what could be called *balancing of performance* than optimization of performance. The components and interrelations between individuals within and between groups are normally described in terms of qualitative data and analyses. Results from effect measurements of human systems at group levels can under certain circumstances be generalized and treated by statistics in order to find human patterns. Studies of individuals are normally treated as specific cases and the results are unique for the situation and are hard to transform to other situations. Admiral Cebrowski addressed this issue as the need for a well balanced force.[9]



Effects of optimization and balance

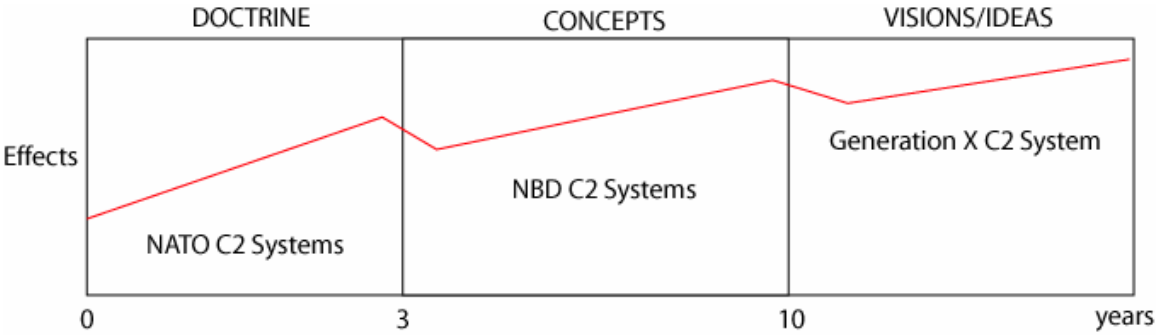
The use of optimizing measurements on human systems will fail in cases where survival is valued higher then achieving maximum optimization. Individuals and groups may show a willingness to self-sacrifice in order to enhance the chances of survival for their families, but will not do that simply to be cost effective. It is hazardous to argue balanced solutions based on optimized measurements. Optimization does not reflect a balanced approach to military effects as it does not include such intangible factors as human emotions, feelings and states of mind such as fear and moral dilemmas, which are central for humans and are not possible to optimize.

Narrow down to the military systems. Another important significant and unique characteristic of the military transformation is to focus only on what is specific for the transformation of the military SoS. But this is not easy. We can find systems in almost any context that are not specific military systems per se but are important for the military transformation. For example is a mobile phone to be considered a specific military system or not? In their own way mobile phones will be studied in a number of different settings and we will follow the results, but in military settings, mobile phones will only be included as systems when they can be used for specific military purposes. This means

[9] Koch (2004:p 5)

that we will focus on SoS in military terms (military tasks, scenarios, etc) rather than on general ones.

Differences in time frames. A third way to categorize SoS is by defining time frames. By time separations we can find different time windows in which different systems are assumed to appear. For example we have systems beyond the next 10 years that today exist only as visions and ideas, and we have in the near future (3-10 years) concepts of systems that we are developing today, and then we have today's systems that we need to adjust to today's situations and coming concepts. This is visualized in the figure below.



Time frames in development

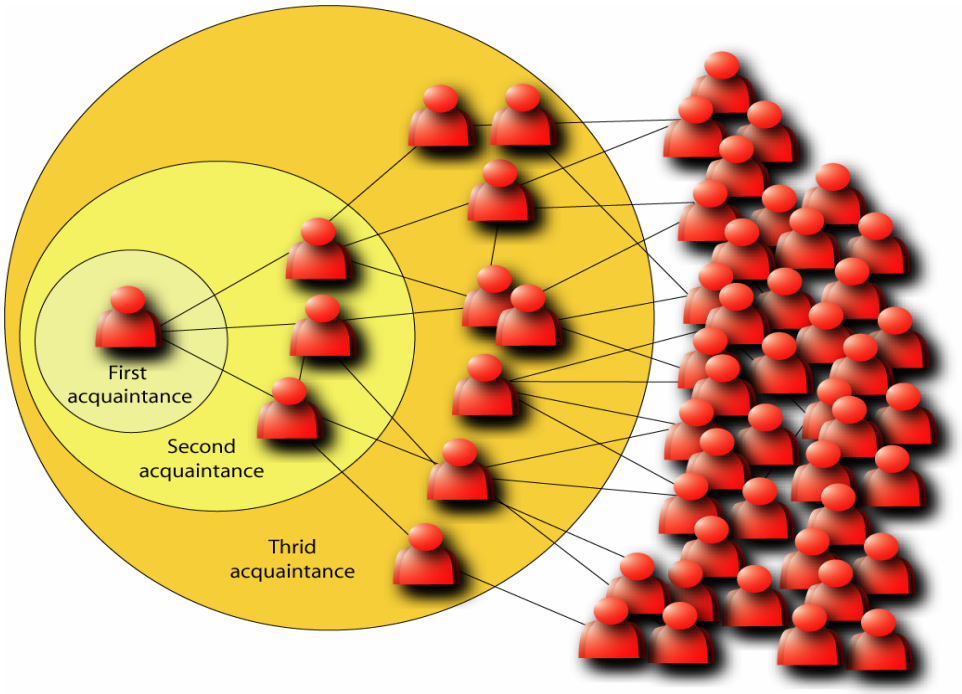
By using time separations in system development we can conceptualize the aims we want to achieve within each time frame. In the actual frame of today, we have doctrines which should be interoperable with NATO. We face the challenge to identify solutions that support the implementations of NATO standards and procedures. But, in the view of the concept time frame this is not sufficient. The goal of concept development is to take the C2 systems to an even higher level of effects than today's systems allow.

Our experience shows that there is a high risk that development tends to focus most on the doctrine timeframe, which is central to our daily business. But, squeezed between the two timeframes, doctrine and visions/ideas we find concept development. Concept development takes time, and needs to be carefully studied before more suitable doctrines may be written. Parallel with the intellectual process of development we have the facts of reality. There is a demand that real world experiences learned from real action should be immediately implemented when they are found useful. The systems-of-systems development should thus consider the dynamics, which are built in through the three different time frames.

To summarize we can say that systems-of-systems may easily become complex, and they differ depending on the context. Above, we have discussed three important perspectives, which set the context. These are *how we consider performance*, *how we focus on the specifics*, and *how we consider time.* In the following text we chose to discuss SoS that focus on balance of performance and on the human perspective, and also how we humans interact in the military planning process during concept development.

How do we know that we know?
Without diverging into an endless philosophical debate of knowledge, we could rephrase the question as what *"guides us in the SoS development"?* We have chosen to use sociograms to study human behaviors in the network-based environment. The concept of sociograms was introduced by psychiatrist Jacob Moreno, in the 1930s to illustrate individuals' social connections. Later, in 1967 psychologist Stanley Milgram found that all individuals on average are only six acquaintances away from any one else on earth. In the mid 1990s powerful networked computers opened new opportunities, and internet software tools were introduced. These relied on the individual's willingness to participate with their contacts. By providing contact information in combination with Milgram's thesis of six acquaintances these tools could find connections to almost any one you would like to meet.[10]

There are obviously a number of problems involved in both theory and practice, but the power of speeding up the links between individuals is believed to give flexibility and be a competitive advantage to the adversary. This is especially the case in international operations where military personnel and civilians must work together under time constraints with little or no coordinated training.



Illustrative example of a social network

By studying the operators and capturing the interrelations with others, we can by using a sociogram describe illustrations and knowledge of the degree and type of connections. This knowledge can be then used to improve organizations and to find important inputs

[10] Fitzgerald (2004)

for physical placements. For the future, we will be able to use the connection patterns within the technical system (mailing lists, plans etc) to design support tools to find the right individuals in specific upcoming situations.

In a pilot study we have used the software Brimstone™. Three preliminary interesting results were achieved:

- First, the results show that at this stage it is not meaningful to explore beyond third acquaintances, since the time it takes to process the links at this leve of complexity does not add enough meaningful information. This might be a result of the relatively limited number of participants in the study. This will be evaluated in more extended studies planned for the future.

- Secondly, the theory of an equation that ahe number of individuals in the organization is a function of the numbers of individuals in the control span and the number of levels still seems to be valid. When more complex issues appear, the number of interactions between individuals seems to decrease in the nodes directly involved, but the number of interactions between individuals in the nodes not directly involved increases. This leads us to the conclusion that we need to find procedures for not overloading connections to the nodes directly involved but at the same time we should be able to supply information to those indirectly involved and searching for information to describe the situation and understand the big picture.

- Thirdly, we could see that the sociogram was in agreement with the existing organization. This is explained by the fact that the missions in the experiment could be described as traditional military tasks. The results looks promising, and sociogram techniques are planned to be used in more complex experiment in which more specific relations will be studied in detail. One of the aspects that we would like to test is Murray's conclusion: "*Evolutionary innovation depends on organizational focus over time rather than guidance by one individual for a short period. Military leadership can affect the process through long-term culture changes rather then short-term decisions*."[11] In this statement we could interpret the long-term solutions and the use for balancing performance, which constitute the systems-of-systems. By using the potential within the social network, the flexibility to handle military and other activities may be increased to minimize uncertainty.

Taking sociograms to the next level

In the first and the second step of development the use of sociograms for the evaluation of human perspectives in SoS might be helpful to illustrate relations between individuals as compared to different organizational (formation) settings. But beyond this we need better techniques to measure and evaluate social perspectives in the network environment. As the third step we plan to investigate the possibility to use what we have named *potentials*. By using potentials we hope to give a more general statistical value to

[11] Murray (1996:p 24)

measure human effects in a format that is comparable with traditional value and verification methods. The technique of potential is based on the same principles as sociograms, which are to be considered as organized in value chains.[12] The principles of value chains are already used in military issues to illustrate the logic in planning of combat. For example in *Guidelines of Operation Planning* (GOP), value chains describe the logic in terms of center of gravity, decisive points, and end-state.

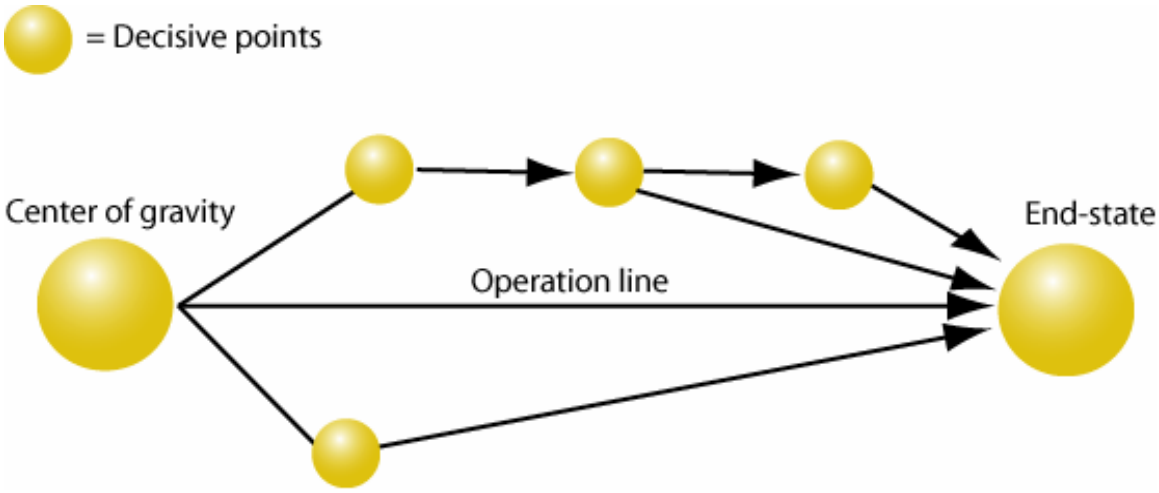


Illustration of components within GOP[13]

Effect in this sense can be described as the function of task and value chain in a certain situation. The situations are dependent on factors such as time pressure, force differences, type and level of uncertainty. However it is not enough to make a traditional risk assessment to create an understanding for the expected effects. Risk assessments normally make use of techniques, methods and administrative routines. We plan in the SoS development to complement data from real measurements with data from expected effects.[14]

Expected effects are considered to be more subjective values than traditional effect measurements. It may be more relevant to consider the conditions to succeed with the end-state (potential) rather then to estimate risks. Potential can then be described as a function of end-state and expected effects. Potential may be described as "*a systems capacity and possibility to achieve certain goals under given time frame and resources*"[15]

[12] An example of value chains are used in economy by Porter (1985).
[13] Swedish Armed Forces (2002)
[14] War as other social activities has been shown to be difficult to capture. An example is Mintzberg (1978) who reported that management could hardly be observed, and researchers need alternative methods to capture the management issues.
[15] Heickerö (2003)

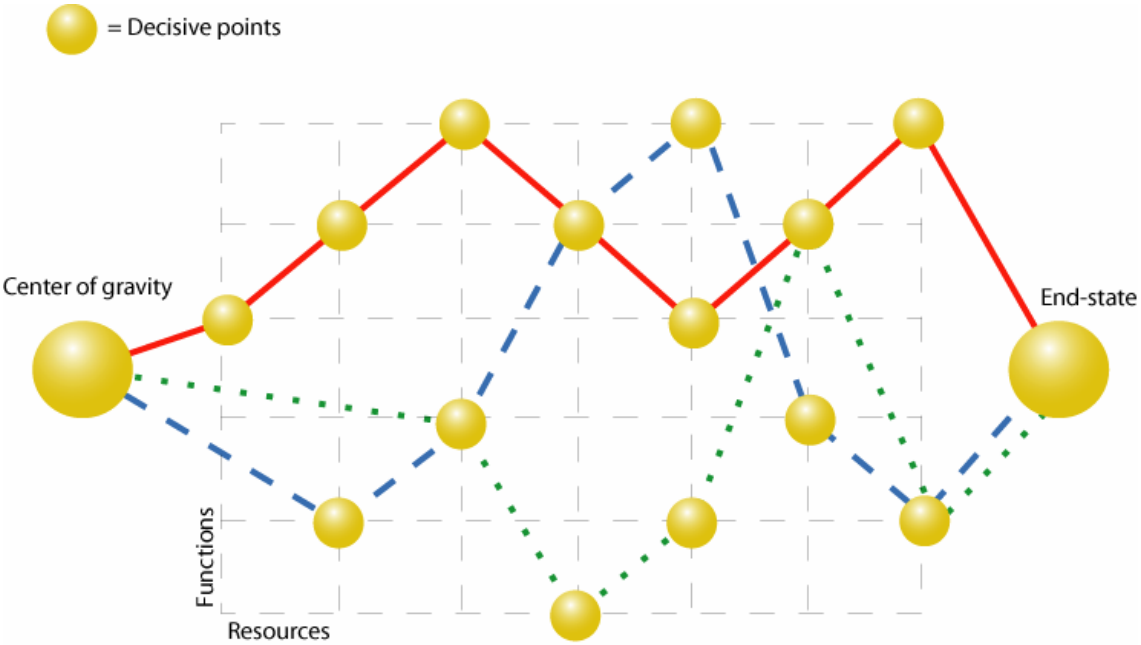


Illustration of value chains trough GOP (the potential grid)

In planning processes, commanders have defined functions and resources, which can be used in a number of different combinations. Different value chains will lead to the aimed for end-state. The puzzle to be solved is to choose the most relevant combinations with maximum potential to succeed.

Coming back to balancing of performance and illustrations of GOP, new forms of value chain descriptions will be needed to balance the technical – and human centric approaches (in the Swedish Armed Forces transformation program and command and control development). Adapting the metaphors from system dynamics[16] with stocks and flows, we now suggest illustrating the GOP as stocks and operational flows, where stocks mean characteristics from different human perspectives and may include values of fear, situation awareness, understanding of the big picture, or moral. The stocks are limited by potential, and the statuses are changed by operational flows. Operational flows are managed by increasing, decreasing or stabilizing[17] the stocks in order to balance the system.

[16] One of the first to use system Dynamics metaphors of stocks and flows was Forrester (1961)
[17] Swedish Armed Forces (2002) descriptions of three status of system control

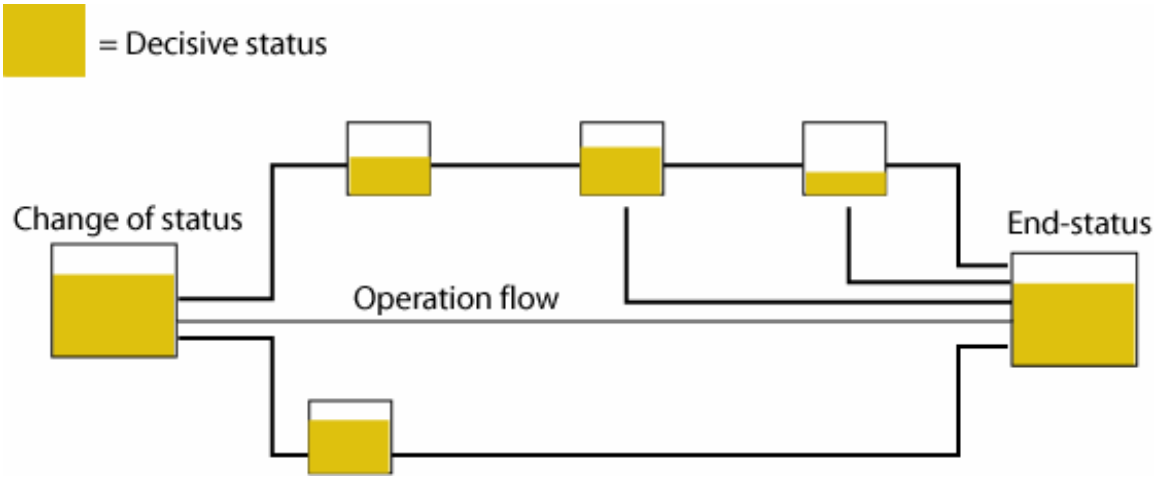


Illustration of components within GOP based on system dynamics metaphor

By being able to manage (balancing a system) over time we will be able to obtain relevant indicators on what the model is executing. The degree of stability indicates what balance we are able to achieve. By combining this approach and taking such human perspectives into account that normally are not considered in traditional valuing and validating techniques, we hope to be more confident in creating the specific properties of evaluation design and data requests by developing tools to answer the question: *What are the new demands for evaluation of systems-of-systems?*

Some final remarks

One of the comments we received when we presented GOP was that "*it is not new, it is like we always have thought*"! This comment gives us more confidence in that today's technical systems and illustrations don't always accurately describe how real individuals think. By introducing concepts such as balance of performance and potential we hope to be able to better illustrate and discuss the human perspectives in systems-of-systems. We hope that these concepts will show the necessity to incorporate the human-centric approach in the transformation program and command and control development and that by using the potential we can to some extent evaluate the human perspectives with traditional value and verification principles of technical systems.

In the coming work we will further develop our thoughts and test them in the Swedish DEMO'05 and 06 experiments. These thoughts will also be introduced to an international case study by the US Office of Force Transformation, called WolfPAC, a study that searches for models that could describe the behaviors of future networks..

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