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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 further argumentation. In this presentation, we focus on some issues a) the network environment, b) what constitute systems of systems, c) how do we know that we know? and d) taking sociogram 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 behavior is so complex that they are literally unpredictable or chaotic¹ 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 shall 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 methodology³, 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. 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 for further argumentation. In this presentation, we will discuss some important issues a) the network environment, b) what constitute systems of systems, c) how do we know that we know?, d) taking sociogram to the next level, and e) some final remarks.

The Network Environment

At first we need to consider the network environment. The threatening picture have changed and with that the military forces needs 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 the most western countries are described as based on systems of systems, although we still have some confusion about what that term

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)

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

In future military missions, the humans will meet different types and degrees of uncertainty and therefore future military organizations needs 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 needed to put more attention to the relations between entities within those networks and to the relations between entities in different networks. Networks are about the relations that forms 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 could be described as technical and human centric networks, with the organizational layer in between.

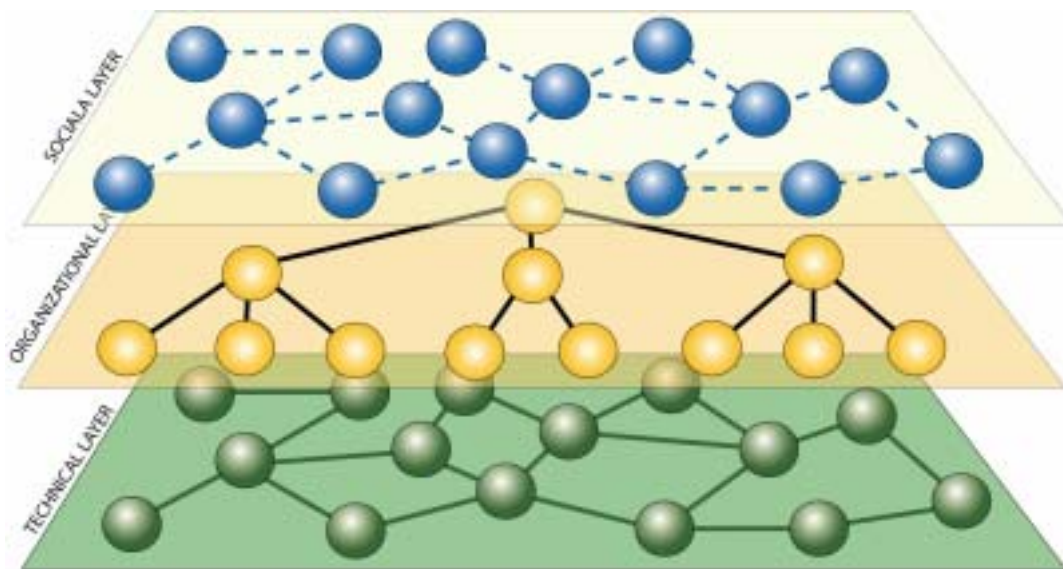


Illustration of the three key networks

As an interesting result, we could observe that the social and the technical networks could be designed with looser connections and could more freely be set up on demand than the organizational layer. This is in agreement with the fact that particularly military organizations are hierarchies and take time to establish to function. These organizations are in the best cases a direct reflections of the activities that they intent to fulfill. For such important activities as war activities we need to be strict on how we give authority to use weapons. An important question for the future is therefore whether only an organizational network will be accepted for war activities including use of lethal weapons?

⁵ Swedish National Defence College (2003)

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 in future environments of war. In this paper we restrict our discussion to just the social layer or the *social network* and we will discuss it as a system. Using a system 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 give us possibilities for theory development and descriptions of systems of systems. We hope by this to bridge the theoretical 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 constitute systems of systems

The term systems of systems (SoS) gives most readers a number of associations. We like to describe SoS as a number of components related together and thereby creating higher effects than if they were used alone.⁶ The reason for integrating systems are mainly to create better 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 what constitute 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 as we believe a successful Armed Forces transformation program and command and control development.

Optimizations of performance versus balancing of performance. SoS could be categorized by the foundation of the system, technical or human. A pure technical SoS could be when two different technical systems are connected together or a pure human SoS could be when human groups are interrelated in social systems. Technical and human scientists have studied these two kinds of SoS separately for ages. However, in reality 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 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. By operational research officers we have learned to optimize processes based on quantitative data and statistical analyses. The baseline for achieving such data are that the systems are well defined, and that the components have recurrent functions.⁸

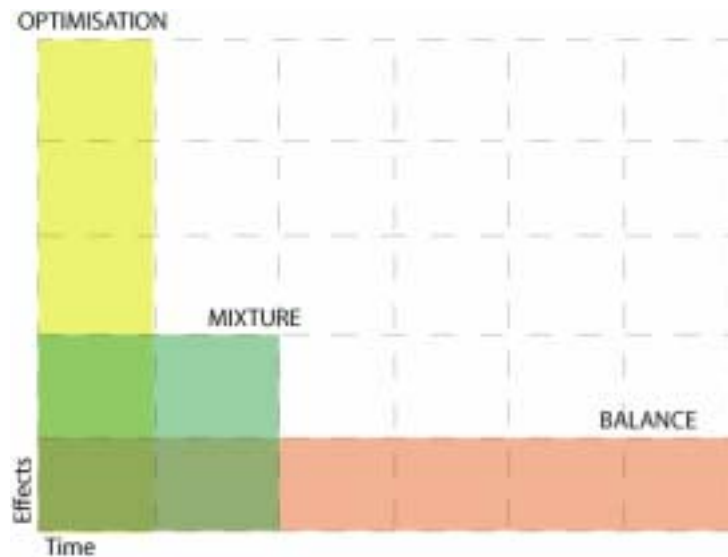
Effects of human systems in military contexts are more often described in terms of survival, which rather concerns what could be called *balancing of performance* than optimization of performance . The components and interrelations between individuals

⁶ van Gigch (2003)

⁷ Murray (1996:p 26)

⁸ E.g. Albert and Hayes 2003:44f arguments on optimization.

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



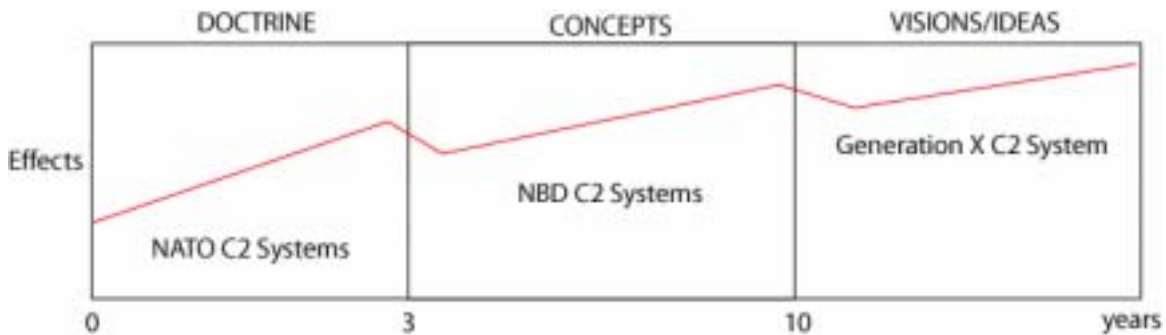
Effects of optimization and balance

The use of optimizing measurements on human systems will fail in cases where survival is valued higher than just finding highest optimized effects. Individuals and groups could show willingness to self sacrifice in order to create survival for their families, but will not do that just to be cost effective. It is hazardous to argue balance 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 minds, such as fear and moral, 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 just focus 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? By their own means mobile phones will be studied in a numbers of different settings and we will follow the results, but in military settings, mobile phones will only be included as systems when we could use them for specific military purposes. This means that we will just focus on SoS in military terms (military tasks, scenarios, etc) rather than in general ones.

⁹ Koch (2004:p 5)

Differences in time frames. A third way to categorize SoS are by time frames. By time separations we could find different time windows in which different systems are assumed to appear. For example we have systems beyond the next 10 years that we have just visions and ideas about, and we have in the near future (3-10 years) concepts of systems that we today try to develop, and then we have today's systems that we need to adjust to today's situations and coming concepts.



Time frames in development

By using time separations in system development we could 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 find 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 system.

Our experience is that it is a high risk that development tend to focus most on the doctrine frame, which is concrete to our daily business. But, squeezed between the two frames, doctrine and visions/ideas we find concept development. Concept development takes time, and need to be carefully studied before any good doctrines may be written. Parallel with the intellectual process of development we have the reality. There is the demand that real world experiences learned from real action should be able to implemented straight ahead when they are found useful. The Systems of systems development should thus consider the dynamics which are build in through the three different time frames.

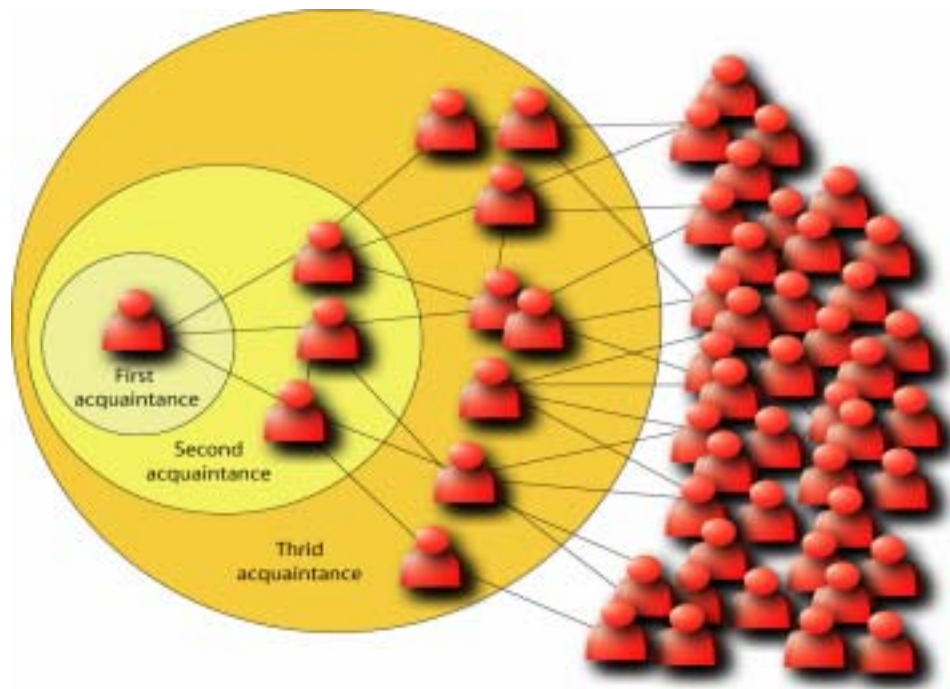
To summarize we could say that systems of systems could easily get complex, and they differ depending on the context. Above we have discussed three important perspectives, which set the context. These are *how we consider performance*, *how we focus to the specifics*, and *how we consider time*. In the following text we chosen 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 losing us into an endless philosophical debate of knowledge, we could rephrase the question what guide us in the SoS development? We have chosen to use sociograms to study the human behaviors in the network based environment. Sociogram was introduced by psychiatrist Jacob Moreno, in 1930s to illustrate individuals social

connections. Later on in 1967 psychologist Stanley Milgram found that all individuals in average are only six acquaintances away for any one on earth. In mid 1990s powerful networked computers give new opportunities, the internet-working software's where introduced. Those software's were built on individuals willingness to participate with their contacts. By providing information about your contacts in combination with Milgram's thesis of six acquaintances those software 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. Especially within international operations where military and civilians should work together under time pressure without almost no coordinated training together.



Illustrative example of a social network

By studying the operators and capture the interrelations with others, we could by sociogram get illustrations and knowledge of degree and type of connections. This knowledge can be used to improve organizations and to find, important inputs for physical placements. For the future, we will be able to use the connect patterns within the technical system (mailing list, plans etc) to design support tools to find the right individuals in a specific upcoming situations.

¹⁰ Fitzgerald (2004)

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 capture beyond third acquaintances, since the time it takes to process the links at this magnitude does not add enough meaningful information. This might be a result of the relative limited number of participants in the study. This will be evaluated in coming more extended studies.
- Secondly, the theory of an equation that the number of individuals in the organization is a function of the numbers of individuals in the control span and the number of levels seems to still 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 increase. This leads us to the fact that we need to find procedures for not overloading connections to the directly involved nodes but at the same time we should be able to produce information to the non-directly involved that search for information to get a situation picture.
- Thirdly, we could see that the sociogram was in agreement with the existing organization. This could be explained by the fact that the missions in the experiment could be described as traditional military tasks. The results looks promising, and the techniques of sociogram is planned to be use in coming more complex experiment in which more specific relations will be studied in detail. One of the things 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, military and other activities might increase the flexibility to handle uncertainty.

Taking sociogram 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 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 statistic value for measure human effects in a format that are comparable with traditional value and verification methods. The technique of potential is based on the same principles as sociogram, 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*

¹¹ Murray (1996:p 24)

¹² An example of value chains are used in economy by Porter (1985).

of *Operation Planning* (GOP), value chains describes the logic in terms of center of gravity, decisive points, and end-state.

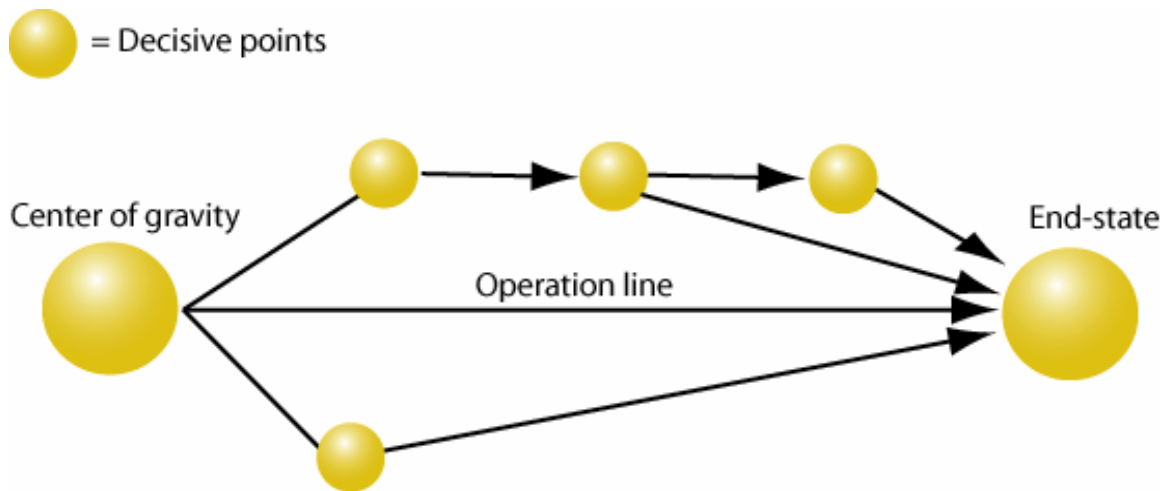


Illustration of components within GOP¹³

Effect in this sense could 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. But it is not enough to make a traditional risk judgment to create an understanding for the expected effects. Risk judgments 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 might be more relevant to consider the conditions to succeed with the end-state (potential) rather than to estimate risks. Potential could then be described as a function of end-state and expected effects. Potential might be described as “*a systems capacity and possibility to achieve certain goals under given time frame and resources*”¹⁵

¹³ Swedish Armed Forces (2002)

¹⁴ War as other social activities have showed to be difficult to capture. An example is Mintzberg (1978) who reported that management could hardly be observed, and researcher's need alternative method to capture the management issues.

¹⁵ Heickerö (2003)

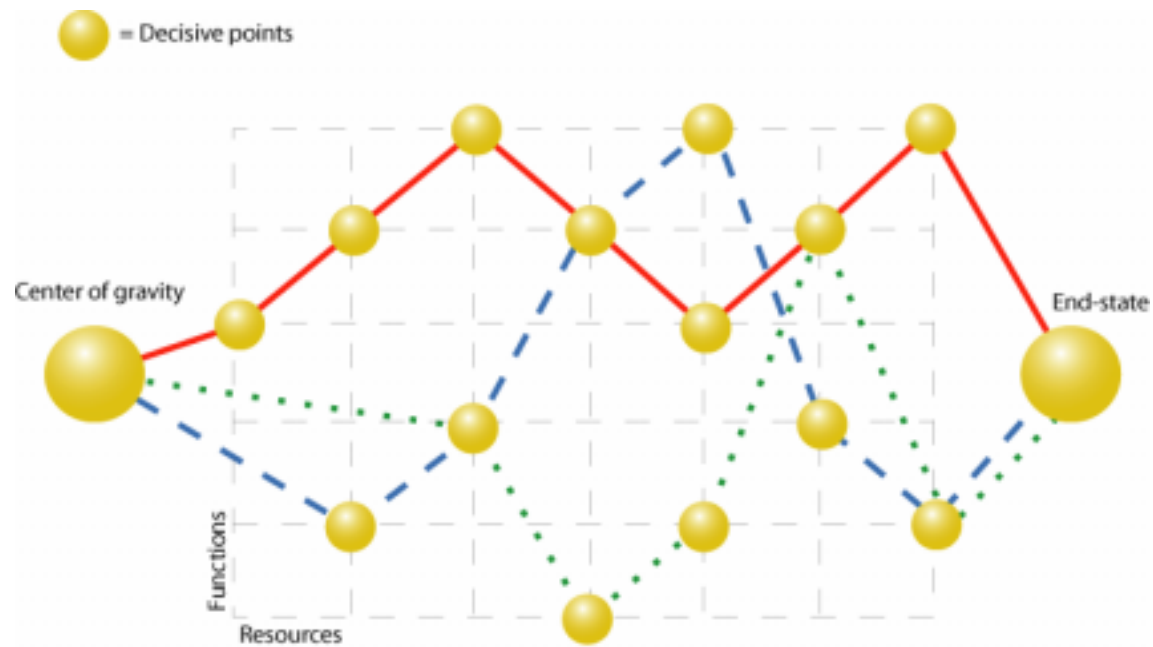


Illustration of value chains through GOP (the potential grid)

In planning processes, Commanders have identified functions and resources, which could be used in a number of different combinations. Different value chains will lead to the aimed end-state. The puzzle is to choose the most relevant combinations with highest potential to succeed.

Coming back to balancing of performance and illustrations of GOP, new form 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). Taking the metaphors from system dynamic¹⁶ with stocks and flows, we now suggest to illustrate 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 big picture, or moral. The stocks are limited by potential, and the statuses are changed by operational flows. Operational flows could be managed by increasing, decreasing or stabilizing¹⁷ 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

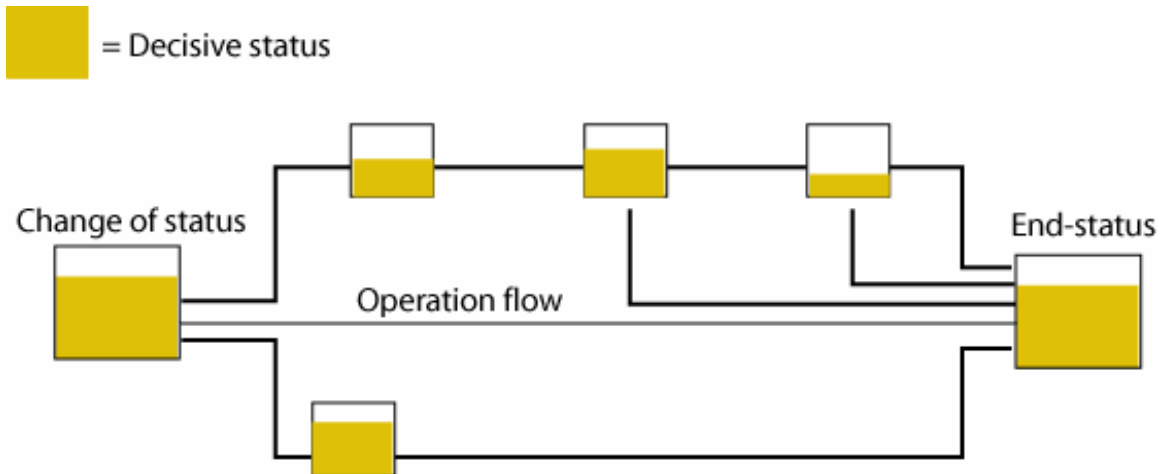


Illustration of components within GOP based on system dynamic metaphor

By being able to manage (balancing a system) over time we will be able to get relevant indicators on what the model is executing. The degree of stability indicates what balance we are able to achieve. By combining this approach taking such human perspectives into account that normally not are 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 getting possibilities to answer the question: What are the new demands of evaluations 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 support how individuals real think. By introducing concepts 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 could 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 future network behaviors.

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