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COAT: Communications Systems Assessment for the Swedish Defence

Suggested topics:
C2 Metrics and Assessment, C2 Technologies and Systems

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Abstract

The transformation of the Swedish Defence has substantially changed and increased the demands on the communication systems needed to support its future missions. Sweden's focus on international missions and most recently, its role as framework nation for the Nordic Battle group, further emphasize this. Demands for interoperability, rapid response, unknown mission areas and heterogeneous operating environments make the assessment of communications systems increasingly hard and complex. Our conclusion is that our traditional methods no longer are satisfactory.

The COAT project aims to develop a user-centric, well-structured and traceable methodology for the assessment of communications systems. The development is focused on capabilities related to the technical parameters of the communications system, but the goal is to provide a method to express how these contribute to higher-level C2 capabilities and, ultimately, to tactical effects.

The methodology should, ideally, be applicable at any point in the life cycle of communications systems, from the study of evolving technologies, R&D, acquisition, operational use, to replacement and decommissioning.

This paper will discuss the ideas behind the project, our methodological approach and some thoughts on the assessment of complex systems.

1. Introduction

This paper describes the current status of a project aimed at improving our current methods for the assessment of communications systems in a tactical and operational context. The project is called COAT, which stands for (unsurprisingly) Communications Assessment. The work is carried out by the Swedish Defence Research Agency, on a research contract from the Swedish Armed Forces. The competencies within the project team include basic radio science, wireless and network technology, information security, systems analysis and scenario techniques. The project is now in it's third and final year.

The aim of the work is to develop, test and implement an improved method that is both well-structured and manageable in practical use. For the method to deliver results of high quality and relevance, it must combine best practice in a number of fields of analysis. Since all assessments necessarily contain an element of subjective judgement, two absolute requirements are transparency and traceability, so conclusions can be linked to individual facts and assumptions.

The most important goal is to provide a bridge between technological and military capabilities. The critical challenge is to assess how a specific communications system contributes to higher system levels effects. The method should ideally go both ways: from technical performance to military capabilities and the other way round.

Acknowledging the fact that many parts of what we need are already in place and practiced in many established disciplines, our general philosophy is to build upon current practice, existing knowledge and best practice in a number of related fields. From this, we have set out to put together a practical method, with a firm eye on the specific problems of assessing communications systems.

The method should be applicable at any stage in the life cycle of a communications system. Examples of applications may be:

- Assessment of system concepts
- Assessment of alternative system
- Assessment of complementary systems
- System under development
- New functions or services in existing systems
- Consequences of phasing out existing systems

Purpose of this paper

Our intention here is not to give a formal description of a complete method for assessment of communications systems. The purpose is rather to discuss our perception of the general problem and our approach to a solution. The immediate goal for our presentation at this symposium to initiate a dialogue with other interested partners.

2. The problem

According to various sources, "assessment" means:

> "The classification of someone or something with respect to its worth"[1]
> "The act or result of judging the worth or value of something or someone"[2]

Common synonyms of assessment are *appraisal*, *estimate*, *rating*, *valuation*, *evaluation* and, most significantly, *judgement*.[3] All these examples clearly connote some element of subjectivity. Indeed, the operative words in the definitions above are "judging" and "value". There is no point in denying that all assessments are fundamentally subjective. Neither is there a real problem: what the customer pays for is the best possible, independent, unbiased judgement. The analyst's plight is then to deliver that, through a systematic process, observing basic principles of science and following best practice in the field.

Value is clearly also context-dependent. What is valuable in one situation may be totally worthless in another. The lesson here is that the context must be specified before an assessment can deliver any meaningful result.

C2 Assessment

Many existing methods are well suited for analysing e g the physical characteristics and performance of individual radio system components, or at the other extreme end, the overall capacity of entire communications infrastructures. For (mobile) radio networks and combined systems, where the complexity is higher, no single reliable assessment method exists. The link from this to higher-level measures such as force effectiveness is of course even more tenuous.

To qualify as a rigorous, analytical method, an assessment method must of course respect and build upon established scientific principles. To be of practical value for the customer, but also for the analysts performing the work, there are additional requirements. Combining all this, we may come up with a number of requirements for an ideal assessment methodology:

- Provide the customer with an unbiased, relevant and timely result
- Report results on a conceptual level and in a language suiting the customer
- Make conclusions, as far as possible, free from personal or organisational bias
- Provide traceability by linking results to all data and assumptions
- Always support, never burden, the assessment team
- Be adaptable to different scope and depth of studies
- Handle contingencies, such as new directives or change in team composition

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[1] http://www.thefreedictionary.com/assessment
2 The New Dictionary of Cultural Literacy, Third Edition. Houghton Mifflin Company, 2002.
[3] Roget's II: The New Thesaurus, Third Edition. Houghton Mifflin Company, 1995

The NATO Code of Best Practice for C2 Assessment[4] is a natural starting point and has served as a guiding framework for us. It is however too comprehensive for our specific needs. On the other hand, one measure of success for our project is whether it can be applied within the COBP framework.

If the COBP Assessment framework is too wide, what is then the scope of COAT? And what sets it apart from other types of studies? In short, COAT is less extensive, more focused on technical systems in a given context. Our focus is on the lower to middle range in terms of system levels: the gap between technical parameters of communications systems and C2 effectiveness.

Starting from actual, perceived needs for better assessments, the COAT method is designed primarily for situations when there is a specific need for:

- Independence: the task has the character of outside review
- Operational relevance, not only technical analysis
- Timely results (early assessment of new technology or near time assessment of existing systems)

For brevity, we will use the acronym CA for the application of the COAT method, as opposed to the method itself.

Current practice

Assessments of various C2 elements are conducted on a regular basis, and the body of methodological knowledge and experience to build upon is indeed extensive. In fact, given the volumes of published material and ongoing research activities, the reader may well ask, what more is there actually to do?

It is our firm belief, after having participated in many earlier studies that our current practice is falling behind the changing demands. The critical insufficiency is the apparent disconnect between analysis of technical performance and capabilities on higher system levels.

Too often, there is also a lack of analytical rigour and transparency. These shortcomings are well known to seasoned practitioners in this field, though perhaps rarely admitted to. At the risk of stating the obvious, let us enumerate just a few sore points: imprecise formulation of the problem, inaccurate data, hidden assumptions, poor quality of analysis, lack of clear documentation, obscure reporting and unsubstantiated conclusions.

Bad assessments waste time and money for the people involved, and, if a bad decision is eventually made based on the result, can entail enormous costs for the taxpayer. There are of course a number of reasons why current practice fails to live up to the

[4] Henceforth called COBP. See [COBP] in the references See also Starr (2003) for an overview of C2 assessment in general and earlier work leading up to the COBP.

ideal: lack of competence, impossible timelines, vested interests and hidden agendas, pressure from industry and political considerations, just to name a few.

No method can entirely make up for these real-world facts, and least we forget in our analytical fervour, good decisions can sometimes actually be made on rather shaky grounds. However, hoping for such good luck hardly constitutes a valid method. As analysts we have an ethical obligation to continually improve our work.

New challenges

There are three main trends that combine to create new challenges for the assessment of future communications systems: larger number of users[5], integration of systems, and introduction of data-rich services. In addition to being largely technology-driven, these trends are also driven by the development of new C2 concepts, conceived to radically improve military capabilities, or just to maintain effectiveness in increasingly complex conflicts.

It could be argued that there are some counter-trends: Many separate, incompatible legacy systems are now being forced out, replaced by fewer, more unified communications platforms. This would seem to make the assessment task easier, since there would be fewer alternatives to evaluate. Also, market-related factors, such as consolidation within the defence industry, would contribute to this. On the other hand, the transition from many old to a few new systems in itself creates a need for more, rather complicated assessment work.

The case of interoperability is particularly interesting: standards-based interoperability and even more so, interoperability through commonality of equipment, would seem to facilitate the situation a lot. However, the devil is as always in the details: Standards is one thing, implementation something different entirely. Even if systems conform to agreed standards, some are more compliant than others, and standards evolve over time. Thus, interoperability issues must be very considered very carefully in most assessments.

For the Swedish Armed Force, these challenges are very real, as a number of existing systems will be have to be replaced, or adapted to new uses, in the near future. Some examples of current and future issues are:

- Personal role and group radios
- Communications for Special Forces
- Next-generation combat radios – Software Defined Radio
- Tactical Data Links – introduction of Link-16
- Next-generation telecom system for national defence
- Long-range communications – HF, Satcom
- Planning for impending tasks - Nordic Battle Group 2008

[5] The “users”, including sensors and information systems, also become much more heterogeneous, each making different demands on the system.

- Capability development - EU Battle Group 2011

Existing methods and supporting tools

When it comes to the actual analysis phase in any assessment, there is a place for all commonly used analytical tools. Nothing can be a priori excluded, and it is hard to point to any specific tools, particularly suited for CA. As always, the tools have to be chosen for the task at hand.

The central problem in all assessments is how to combine many different measurements and estimates, measured on different scales, into compound values. One specific supporting method we have evaluated in our project is the Analytical Hierarchy Analysis (AHP)[6], but many other multi-criteria methods are possible candidates.

For detailed modelling and simulation of communications systems, there are well-established tools, such as OPNET[7]. Netwars[8], which lays a geographical and organisational layer on top of OPNET, is particularly interesting. We have studied how it can be used for typical assessment tasks. As Netwars is the tool recommended by the US Joint Forces Command, for all communications-related analysis in the USA, it may well gain wider use also internationally In fact, the tool is currently being introduced within the Swedish Armed Forces and the Swedish Defence Material Agency.

As noted in the introduction, we are well aware that parts of what we need are already present in many established methods. However, we would argue that most of these are much too cumbersome and constraining to be adopted wholesale for our purposes.

For instance, in the software development field, there exist a number of standardised methods and tools, to handle a range of tasks, from user requirements to system design and change management. Some examples are the Rational Unified Process (RUP), Architecture Tradeoff Analysis Method (ATAM)[9] and Common Criteria for Security Evaluation (CC)[10].

These methods, and others, are heavily used also within military Systems Engineering and Capability Development. As with any successful product, there is a temptation to use them far outside the area they were designed for. The temptation may be even stronger in fields that are relatively less mature or unstructured. C2 Assessment certainly falls in this category. In our view, tools follow methods and methods follow tasks. CA is not the same as requirements management or systems engineering.

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6 Saaty, T. L. (1990). For a more recent account, see Saaty, T. L. (2005)
[7] http://www.opnet.com.
[8] http://www.disa.mil/netwars
[9] http://www.sei.cmu.edu/architecture/ata_method.html. See also Clements et al (2002)
[10] http://www.commoncriteriaportal.org . See also Common Criteria (2006) in the references.

As architectural frameworks, such as DoDAF/MoDAF gain wider acceptance, as descriptive tools, also in the capability development community, assessment teams may well encounter demands that these be used in all documentation.

3. The COAT approach

This section gives an overview of the approach we have taken, and then tested. The description should be understood as an ideal process. In order to be practical, the time and effort put into each step must be adapted to the actual circumstances. Indeed, one of the most important things may be to indicate what "shortcuts" can be taken, without forsaking quality.

As always, the usual remarks of process descriptions apply: boundaries between steps are inherently fuzzy, and although presented here as a simple chain of activities, it is of course an iterative process, where earlier steps must frequently be revisited.

Customer dialogue

The COBP lists a number of roles that are involved in assessment work. For us, "customer" is the person or organisation that gives the task and to whom the assessment team reports back.

A necessary condition for any successful study is of course that the right question is answered. This may seem tremendously obvious but this is probably the most common point of failure. In all but the most trivial cases, the system in focus is complicated in itself, and putting it into a relevant context further complicates the task of finding a clear and precise problem formulation.

Therefore, a constructive customer dialogue is of decisive importance. This is discussed at some length in the COBP, so we do not have to dwell upon it here. We use a semi-structured interview form, supported by a document containing a set of prepared questions. Interviews with different persons should be documented separately, in order to be able to trace what assumptions come from where.

In the analytical community, the received wisdom says that people often do not know what they want: ”First find out what the question is – then find out what the real question is.” There is actually a corollary to this statement: ”and then find out what part of that question can actually be answered”. Even if we can formulate the ”real” question, it may prove too hard to answer within the constraints of available time and money.

The customer dialogue must result in an agreed formulation of the problem, expressed in the projects' Terms of Reference. It must also make clear the purpose of assessment. The assessment team leader must have a clear understanding of why the task is given and in what context the result will be used. This will guide the team leader in defining the scope and depth of the study, but equally important, the form and language of the reporting. It should also help all team members to understand the operational context

of the problem. To achieve this will normally require the participation of several subject matter experts.

Apart from obvious communications-specific attributes, applications of this method will always entail the study of many other aspects of the system and its environment. The number of attributes that can potentially be analysed is vast in any system of practical interest. It is therefore necessary to agree upon what key aspects the assessment should focus on. Examples of such broad assessment areas can be:

- Personnel and training
- Support systems
- Lead times (e g for acquisition and deployment)
- Economy and market factors
- Security and safety

Sometimes it is the express purpose of the customer to get a broad and superficial analysis of a system. Otherwise, the temptation to include a large set of aspects should generally be resisted, since breadth can only be achieved at the cost of precision. In any case, these areas must be agreed upon, preferably prioritised, and then put down in the Terms of Reference.

The customer dialogue frequently will require a number of iterations, but sooner rather than later, the assessment team must take over full responsibility for the work. Further interaction with the customer should ideally be limited to predetermined progress reports. In practice, the team will likely have to turn to the customer or his representatives to get further data or subject matter expertise.

Planning and preparation

Once there is agreement on the problem formulation, planning and preparation for the actual assessment work can proceed. The input at this stage is the agreed Terms of Reference from the customer dialogue; the output is a set of planning documents. This is not really different from any other kind of study, but the documentation plan is of special importance, since it is the primary vehicle to deliver the necessary traceability and transparency. Apart from a traditional project break-down structure, the plans must specify identified subject matter experts and other data sources.

Modelling

When the problem formulation is agreed upon, the first step is to define a set of top-level measures-of-merit within the assessment areas previously agreed upon. The next step is to define and model the system in focus: the elements of the communications system that should be assessed. The art here, as in all modelling work, is to keep just the right amount of detail. Relevance to the given problem always trumps fidelity. If necessary, additional details can always be added at a later stage.

It is of course very different to assess future systems based on emerging technologies or evolving standards, than existing system. In the latter case, a lot hard data can be

obtained. In the former case, the analysis will rest entirely upon assumptions about possible implementation and use.

The next step is to define a relevant operational context within which the communications system can be analysed. We use scenario methods to do this. Since constructing a scenario from scratch can be a very time-consuming activity, it is generally far better to start from some existing scenario. In some cases, the customer may actually demand that a set of standard scenarios should be used.

Regardless of where the scenarios come from, the main work for the assessment team is to formulate a number of smaller use cases or vignettes, within the framework of the overall scenario. These will set the scene for communications-related activities. To be useful, the description must define a situation or specific event, a military task to perform, the units and other actors involved and relevant parts of the encompassing C2 system.

This is a time-consuming part of the work, and therefore it is tempting (or plain necessary) to limit the number of vignettes. The price for this is that it will be harder to draw more general conclusions from the analysis.

Analysis

The actual analysis is of course the core of the assessment work. Even if this is the most intensive part of the work, it is not necessarily the phase of longest duration.

As clearly stated in the COBP, there is no single method or general tool to use in all possible situations. Even in our limited implementation of the COBP framework, the choice of analytical tools and methods must be left to the assessment team.

In our tests we have used a rather traditional top-down breakdown of the problem into smaller parts that are assessed separately, followed by a bottom-up aggregation of lower-level assessments. This approach has the clear advantage of starting from the customer’s perspective and his expressed needs in terms of capabilities. Trying to start from the bottom with technical components carries the risk of getting lost in details that ultimately does not affect the final result.

On the other hand, such a traditional, simple hierarchical breakdown has many, well-known limitations: any sufficiently complex system has so many interactions between its components that cannot be represented in this way. This will certainly be the case when the assessment includes the effects of user interactions, but also for relatively simple systems, when analysing any system-wide aspect, such as economy or security. Even from a purely technical perspective, the dependencies between different system components can be strong. For instance, a deficiency in one part of the system can often be overcome by a number of compensating measures in other parts. Which particular configuration to assess is up to the team, and all such choices must be clearly documented.

If the approach of breakdown and aggregation is taken, it is important to formulate conclusions on every level, in a language that is relevant and comprehensible for the customer. Just summing quantitative measures all the way to the top makes the final leap from technical terms to the customer's world very hard, and the whole exercise would hardly be different from a traditional, technology-based assessment.

There are of course alternatives to traditional top-down analysis. As these are well described in many standard texts, we only give some short comments here; for technical modelling work, the use of complementary and overlapping models, while costly, can give a much better understanding of the true complexities and reduce some uncertainties. Issues related to tactical use may benefit from an actor analysis, viewing the problem from the position of various interested parties:

In our tests, we have elected to adopt a "needs-based[11]" hierarchical scheme, where we start from the top-level, user-formulated needs, and recursively decompose these into lower-level "needs". For each need identified, we define and measure[12] relevant properties and then estimate to what degree the need can be satisfied by the target system. Aggregating these measures upwards to the top level could then give an overall assessment of how well the system as a whole Although this has been our main approach, it is by no means the only possible, and no other parts in or method depend critically on this choice.

Synthesis

At the conclusion of the analytical phase, we have a large body of technical results and some conclusions concerning parts of the system, including a tentative valuation of the system as a whole. Before a comprehensive answer can be given to the original question, all these parts must be weighed together. The synthesis is where three rather obvious questions must be answered:

- What is the overall result?
- How sure are we of that result?
- How general is that result?

In essence, the second question asks how the result depends on known uncertainties in all models, data and assumptions. This can be seen as a complex sensitivity analysis, although in practice it will rely more on informed judgements than calculations.

The third question asks under what range of circumstances the result holds? The analyst must cut down and delimit the problem to make it tractable; the customer needs a robust answer of fairly wide generality. One way to achieve this is to reason about likely consequences of larger, qualitative variations, outside the boundaries of

[11] We use the term "needs" instead of "requirements", but the semantics may be confused in the translation from Swedish. To us, *needs* is closer to the user perspective, and can be partly satisfied, while *requirements* (again, to us) is a more technical term and are either wholly fulfilled or not at all.

[12] Not seldom, the "measurement" will actually be best estimates to the best of knowledge. Once again, documentation of who made the estimate, based on what, is essential to

the actual analysis. Examples may be: “What happens if we move the scenario from Africa to Central Asia?” “What if the threat level is very different?”

This may also be the time to have all or parts of the work reviewed by some party outside the assessment team.

4. Pilot Assessments

In our work, we have adopted a ”learn as you go” approach. Instead of constructing a complete process right away, we have tried to develop the methodology step by step, testing each part in small-scale tests.

Vignettes

To test selected parts in the method, we have created small vignettes . These have been written very quickly, without much detail. Additional detail needed to proceed has been invented “on the spot”, without any concern for accuracy. The actual outcomes are largely discarded, as the point is to learn how the methodological step can be applied. To give an impression of the character of these vignettes, this is a list we conceived:

- Swedish Forces assume command of multinational peace-enforcement brigade
- Humanitarian assistance: Support of a large refugee camp
- New long-range communications system for Swedish embassies abroad
- Upgrade of national TETRA system for public safety
- Wireless staff workplace: Information security issues
- Humanitarian assistance – Transport of relief material

In practice, we found that it was better to reuse a few, so only the first and the last were expanded in any detail.

Pilot test

Each year we have performed a larger pilot test, putting together all parts so far developed and applied it within a fictive assessment task. To cover many of the typical roles involved, and with limited access to military personnel, we have used loose role-play as a method to make tests a bit more realistic. For instance, we have performed mock customer dialogues, and produced various initiating and planning documents, including administrative details as budget and deadlines. Having a written Terms of Reference is crucial for the test: at the end, we must check if the conclusions actually give a satisfactory answer to the agreed problem formulation.

For the first two tests, we developed and used a scenario covering a multi-national peace-support operation in Western Africa, set in the immediate future. The system we evaluated was a local Wi-Max system, built from COTS products. This would serve as an independent complement to the forces organic equipment, providing extra capacity for non-critical services. With the system in focus and overall type of operation given, the problem we set ourselves was simply:

> "Describe the possible additional values that commercially available systems, based on the Wi-Max and Wi-Fi standards, can provide to a large, long-term peace support operation"

We delimited the study geographically to the SPOD[13] area, containing a large harbour, with critical logistics infrastructure, local government and humanitarian organisations. Functionally, we restricted the study to local area surveillance, logistics support, co-ordination with civilian actors, and welfare communications.

The motivation for the choice of a COTS system was a genuine interest in how these could work. On paper, they have several attractive properties, such as flexibility, small logistics load, low cost of acquisition and maintenance. At the end of the mission, it could possibly be left behind, to function as a temporary "Internet Service Provider" for the actors remaining in place.

The only function studied in the first year was point and area surveillance. The focus question was whether a camera-surveillance system supported by a combination of Wi-Fi and Wi-Max networks could replace soldiers, thus freeing them for other, core mission tasks. In the second year, the test was extended in two ways, to increase the complexity of the situation: first, the Wi-Max system was extended with a number of extra base stations, introducing e g the need for network planning. Secondly, another use case was added, describing the logistics management through the SPOD and onwards.

As the real object of the tests was our methodological approach, and not the Wi-Max system in itself, we will not report the assessment results here. The important results were the lessons learned from applying the method, which went in to the further development of the method.

5. Further work

Further testing, analysis and documentation

The main activity in the last part of our work is a test of all parts in a more realistic setting. We have chosen to make an assessment of the system design for the communications system for the new Nordic Battle Group. This is a multinational, rapid response force, consisting of a core battalion, supported by a large array of Combat Support and Combat Service Support elements. With Sweden as framework nation, it will be placed under the European Union's Military Committee's command and stand at ten days readiness during the first half of 2008.

[13] Sea Port of Debarcation

At this stage, we have performed the customer dialogue and initial planning. The test period continues up to mid-autumn. The final formulation of the COAT method will thus have to await this test and subsequent analysis.

Validation

Validation of the method as such is obviously hard to do. One possible way to achieve this is to have the result of our final test evaluated by a prospective customer, not involved in the test. The analytical work and documentation can be controlled through peer review.

An interesting question is how we can measure improvement. What is actually the baseline here? The tests we have made are essentially naturalistic experiments. It is obviously not practical to make a strictly controlled experiment, performing the same task with and without the COAT method. One suggestion is to compare the test results with a quick-and-dirty "gut-level," assessment by a subject matter expert with extensive professional experience.

Reporting and implementation

A method that cannot be transferred to other people than those involved in its conception cannot pretend to be scientific. On the other hand, as pointed out, all assessments contain an element of professional judgement. Frequently, ad-hoc assumptions and rough estimates must be made, based on experience more than hard data.

We have at many occasions had to ask ourselves what the actual deliverable from the project will look like. Our position is that the method, just as the full COBP for C2 assessment, is a framework and that it is not meaningful to restrict the prospective users by giving details how to apply each step. This raises the questions of how to present the result, and how to help implement its use. We can foresee a number of complementing ways to disseminate our results:

- Direct participation in future assessment tasks
- Master-Apprenticeships
- Courses and training
- Publications
- Workshops

Remaining questions

After the completion of our final test, there are still a number of questions that can only be answered through practical application in real assessment tasks. Some are common to assessment in general, some are more linked to our specific approach: Examples are:

Is extensive documentation sufficient to achieve transparency and hence, traceability? Clearly, too much documentation creates obscurity and may hide important details as well as all sorts of bias and other flaws – either by accident or by design.

Is our "needs-based" approach general enough to handle all sorts of problems? Is it possible to actually formulate true user needs? Can it be applied in more open-ended assessments of evolving technology?

Will the method be perceived as too complicated or burdensome by potential users? Will this approach be practically useful, given typical timeframes and budgets to perform the task?

How can the outlined method be adapted to small tasks, performed by an individual or very small group? What short-cuts can be taken through the many steps and processes? What parts must be kept, what can be left out or handled superficially?

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