Guiding Experimentation Efforts in Support of Transformation

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Abstract

In the context of transforming military forces, activities in Concept Development & Experimentation (CD&E) are increasingly seen as important with respect to the realization of needed capabilities in areas where there are no established solutions. Limited funding leads to a need for prioritization of proposed experiments. This paper describes a methodology that helps prioritize experimental activities on the basis of operational values, costs and risk profiles. The methodology has been developed in the project METEX (METhod for EXperimentation) conducted by Norwegian Defence Research Establishment (FFI) and Teleplan AS in Norway.

The paper describes a decision support tool for prioritization of experimental activities based on operational need, operational value and the estimated cost and risk. For assessing operational value, a network centric representation of the force structure is applied. The use of properties and gaps in this representation of the force structure is crucial in the methodology.

The paper also briefly describes a web-based process framework, in which the assessment tool is incorporated. The web based framework serves as a guide through the experimentation process.

The Norwegian Armed Forces plan to implement the methodology and associated process within this year (2004) to support the CD&E process.

Introduction

The wide spectrum of current and future security challenges impose new requirements on our Armed Forces. As a result there is a need for adapting the defense thinking, planning and defense structures. The overall goal is to have interoperable and usable forces available, when they are needed, where they are needed, and with the capabilities that are needed.

Transformation means re-shaping the military body to give it the necessary agility, punch, technique and mobility to make it usable in present and future security scenarios.

Transformation implies a focus on developing new concepts, how to do things better, experimenting with solutions to verify or falsify hypotheses regarding operational value, and demonstrating and finalizing some of these solutions.

Concept Development and Experimentation (CD&E) is often looked upon as a vehicle for moving along the road of transformation. A properly focused, well balanced, and expertly conducted CD&E program is paramount to take full advantage of the opportunities that information age concepts and technologies offer.

CD&E activities will partially emerge from top-down initiatives based on identification of capability gaps relative to plans for needed capabilities, and partially on bottom-up initiatives (shortfalls and "good ideas") originating from communities concerned with e.g. operations, R&D or training.

The Joint Operational Headquarter in Norway has been given the responsibility for coordinating all national operationally related experimentation, and due to limited resources, a framework to facilitate prioritization of proposed experiments is needed. Experiments are likely to have different cost and risk profiles which should be weighted against the potential operational benefit of the associated concept.

The prioritization framework should also support a process, which balances top down initiatives and bottom up creativity. Identification of capability gaps will form a basis for prioritizing initiatives.

This paper describes a framework and a decision support tool for prioritization of experimental activities based on operational need (capability gap), operational value (to which extent operational capabilities are to be enhanced) and the estimated cost and risk of the experiment. The framework is currently under final development and evaluation by the Norwegian Defence Research Establishment (FFI) and Teleplan AS in a project denoted METEX (METhod for EXperimentation).

The Norwegian Armed Forces plan to implement the methodology and associated process within this year (2004) to support the future CD&E process.

CD&E process

The concept development process begins with the identification of a concept idea and runs through concept exploration, further development and refinement until completed concept evaluation. In this paper the CD&E process is divided into the four, partially overlapping processes: *identify*, *develop*, *experiment* and *evaluate.*

Figure 1 illustrates the CD&E process as a linear four-step process. However, in real life concepts are developed through several parallel and iterative processes. For instance, the development of an overarching warfare concept may be accomplished by maturing a number of identified ideas trough parallel iterations of the succeeding steps: identify, develop, experiment and evaluate.

New developments typically start by arranging workshops and seminars and performing studies/analysis. Then it may be followed by simulations and gaming, before carrying out more practical tests, such as CAX/CPX or field exercises. When the concept has reached a satisfactory level of maturity the development process is completed by larger tests/demonstrations, where a major field exercise *may* be used as an arena. Final experiments, which are arranged as demonstrations, are often well suited for addressing a wider audience and decision makers.

Identify

In this phase trends and ideas are explored in order to identify new concepts worthwhile pursuing for further exploration, development and experimentation. These ideas may originate from a military unit, research organization or industry etc., and should have a potential for providing new and/or improved operational capabilities. Overarching "top-down" concepts contributes to new capabilities in the long term where as "bottom-up" concepts often are aimed at improving existing capabilities or fixing shortfalls in the short term. The "top-down" and "bottom-up" developments both have a clear justification and should exist side by side, complementing each other.

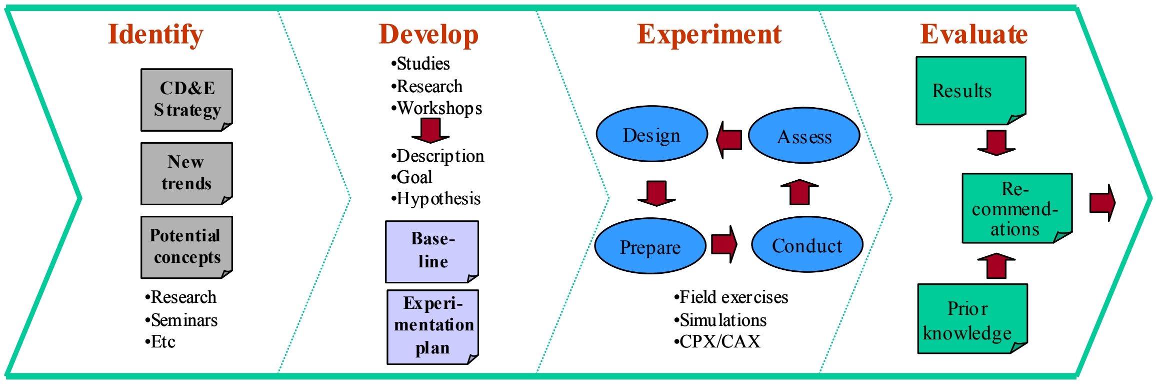

Figure 1: Concept Development & Experimentation as a four-step process

Develop

In this phase the concept idea is explored and developed through workshops, seminars, studies and analysis to prepare for practical experimentation. Potential methods and techniques for analyzing the concept are explored and compared (Figure 2). A documentation of the concept and how it may be implemented along with one or several hypothesis for expected operational value are developed.

Experiment

In this phase the complete concept, or parts of it, is developed through experimentation. "Experiments" in this context may be simulations, gaming, small-scale field exercises early in the development process or a larger/more complex demonstration experiment toward the end of a concept development (see Figure 2).

The main purpose of experimentation is to verify whether a hypothesis or the goal of the concept is feasible or not. An experiment that failed to give the expected results, regardless of the experimentation method, might in principle be just as useful as an experiment that did give the expected results. Normally, the conclusion of an experiment is that the concept is either rejected or recommended for further development. Alternatively, new ideas are identified from the experiment. Both "top-down" and "bottom-up" concepts should be tied to an overarching concept.

Experiments require a minimum of scientific foundation in order to obtain valid results. This may lead to extensive requirements regarding methodology, metrics and documentation[1].

Evaluate

In the evaluation phase the results and findings from the experiment are analyzed and compared with findings and lessons learned from previous experiments. Based on the analysis and increased knowledge on the concept, recommendations for further work are made.

Framework for assessing CD&E activities

A framework based on a Network Centric Component Model is used as a basis for prioritizing CD&E activities. This framework has been established in order to assess to what extent an experiment will contribute to filling a gap in the force structure.

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[1] US DoD Command and Control Research Program - Code of Best Practice for Experimentation.

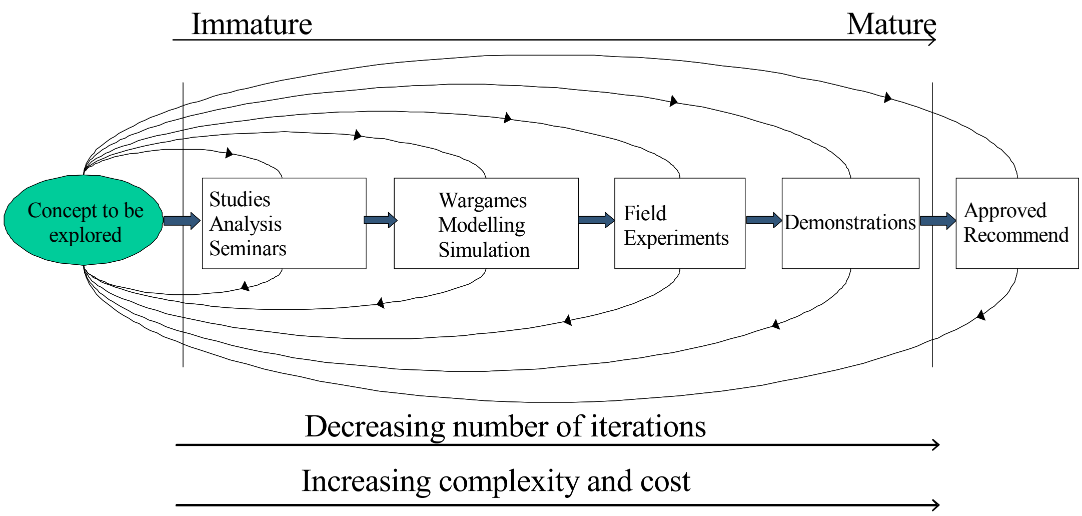

Figure 2: Process and tools for maturing and developing concepts[2]

The Component model consists of four building blocks as shown in Figure 3[3]:

1) A decision component, which consists of decision support and "decision-making" and which deliver decisions, 2) A sensor component, which delivers data and information from sensors, 3) An effector component, which delivers "effects" in operations (both effects obtained directly and indirectly from weapons and other effects that is important for the conduct of operations) and 4) An information infrastructure (INI), which delivers connectivity and distribution capacity for data and information. The INI focus is on communication infrastructure and infrastructure management.

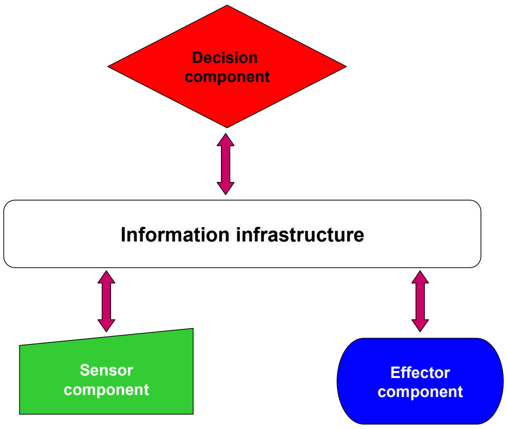

Figure 3: Component model used for representing the force structure

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[2] Based on ideas from UK Command and Battlespace Management and Canadian Forces Experimentation Centre (Plan Pegasus).

[3] This model is based on a model developed in the project "Digitization of the battlefield" (SLADI) at the Norwegian Defence Research Establishment.

The decision, sensor and effector components are divided into sub-areas covering different command levels when it comes to the decision component and different operational environments for the effector and sensor component, see Figure 4.[4]

The force structure shall fulfill certain properties. These properties must be chosen so that they are relevant with respect to possible missions for the military units. They should be determined on the basis of top level prioritizations for the force structure. Some properties are common for all components and some are specific with respect to certain components:

- Common properties (for all components)
  - *Robustness,* determined by physical and electromagnetic survivability, security and logistical aspects.
  - *Interoperability,* determined by the ability to operate together and coordinated with other components (SOP, language, organization, standardization, technology, doctrine, culture).
  - *Speed and flexibility,* determined by the range of possible mission types and operational tempo.
  - *Responsiveness and strategic deployability,* determined by the ability to be deployed and redeployed in a strategically context.
- Component specific properties
  - *Decision effectiveness* for the decision component, determined by the ability for effective decision-making. This is determined by the ability to establish a relevant situation picture (including tools supporting presentation, analysis and simulations), the knowledge and experience for decision makers and staff personnel and the existing culture.
  - *Coverage and data quality* for the sensor component, determined by the ability to catch the relevant amount of data and represent these data correctly.
  - *Effect* for the effector component, determined by the ability to impact targets and obtain other desired effects.
  - *Connectivity and distribution capacity* for the INI determined by the number of connection points (mobile or fixed) and transmission capability.

Figure 4 shows how gaps in the force structure can be displayed. Red indicates critical gaps, yellow indicates substantial gaps and green represents satisfactory status. The colors are given by the current as-is situation. The gaps are given at a fairly aggregate level, but are supposed to be satisfactory with respect to prioritization of experimental activities at an overarching level (operational/strategic)[5].

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[4] The operational environments are interpreted as the area in which the component (sensor, effector) has its impact. For example, an elevated sensor might see into the land environment, and if it does, it contributes to sensor coverage in that environment (land).

[5] For prioritization of activities at a lower level, for instance in the different services, the structure must be represented is a somewhat different manner; Separate matrixes should be developed.

	Component specific properties			Common properties			
	Decision effectivness						
Decision component	Establish situational picture (T)	Knowledge and experience	Culture	Robustness	Inter-operability	Speed and flexibility	Responsiveness and strategic deployability
Operational level	2	1	3	2	3	3	2
Tactical level	2	3	1	3	3	1	2
Sensor component	**Coverage and data quality**						
Psyops	2			3	3	1	1
CNO	2			3	2	3	3
EW	1			2	2	1	2
Land	2			2	3	3	1
Surface	2			2	1	2	1
Sub sea	1			2	1	2	1
Air	2			3	1	2	2
Space	1			2	2	1	3
Effector component	**Effect**						
Psyops	2			2	2	1	3
CNO	1			3	3	2	3
EW	3			3	2	2	1
Land	2			2	2	2	2
Surface	2			2	2	2	2
Sub sea	1			2	3	2	2
Air	1			1	2	1	2
Space	3			3	3	1	2
Information infrastructure, INI	**Connectivity and distribution capacity**						
INI	2			1	3	2	2

Figure 4: Exemplified (not real) representation of gaps in the component based force structure with respect to properties. Red indicates critical gaps, yellow indicates substantial gaps and green represents satisfactory status.

Decision support tool

METEX has developed a decision support tool based on the above framework that will be used when prioritizing experiments. The tool gives important indications of whether or not an actual experiment should be conducted. It should be noted, however, that the value of the tool itself increases as more and more experiments are assessed; it is in the comparison of different experiments that the value of the tool is demonstrated.

The tool consists of four modules supporting each of the following tasks:

1) Assessing the operational value (benefit) of the experiment.

2) Calculating the costs of the experiment.

3) Calculating the benefit/cost ratio of the experiment.

4) Assessing the uncertainties associated with the conduct of the experiment.

First, associated with task 1), the operational value of an experiment is evaluated due to the following procedure where the matrix in Figure 5 is applied:

a) Find the points in the matrix given by components and associated properties related to the experiment

b) Set a score in the blue frame (Figure 5) next to those points, reflecting to what extent the gap are addressed. A score set to 1, reflects some influence on the gap, and a maximum score at 3 reflects heavy influence of the experiment on that gap.

c) These scores are multiplied with the respective gaps (1 for green, 2 for yellow and 3 for red) and the products are summed up for each component.

d) The operational value of the experiment is calculated as a sum of all total scores for all the components (see Figure 5)[6].

By default there is always “gaps” (set to 3 in the matrix) in the property “cost/effectiveness”, meaning that improvements in cost/effectiveness, without necessary influencing the other properties, will always be considered and prioritized accordingly.

Associated with task 2) there is a module in the support tool that helps calculate the cost of an experiment. This module helps calculate costs associated with manpower, equipment, suppliers and administration.

Task 3) is to calculate the benefit/cost ratio of the experiment by taking the numbers for benefit and cost and place those in a diagram for comparison with other experiments (Figure 6). The number defined by dividing the score from task 1) with the cost from task 2) is also calculated, as in Figure 6, where the actual experiment (in black) is compared to other experiments (shaded).

Task 4 is to assess the uncertainty for the conduct of the experiment, for instance in terms such as:

a) Probability for not getting access to equipment, infrastructure and personnel.

b) Probability that uncontrollable factors (such as weather) will influence the validity of the experiment in a negative way.

c) Probability that external suppliers cannot deliver to estimated cost and quality.

In that way a “risk profile” for the feasibility of the experiment can be obtained, and this profile is also an important factor in the assessment of the experiment.

Going through the four tasks for each experiment in a portfolio of experiments will thus give a basis for prioritization of which experiments to conduct (fund).

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[6] There is also an option for addressing the significance (weight) of a property. In Figure 5 this significance is set to the (arbitrary) value of 3 for all properties.

	Component specific properties						Common properties										
	Decision effectiveness																
Decision Component	Establish situational picture		Knwledge and experience		Culture		Robustness		Interoperability		Speed and flexibility		Responsiveness and strategic deployability		Cost-/ Effectiveness		Score
Significance	3		3		3		3		3		3		3		3		
	Status	Score	Status	Score	Status	Score	Status	Score	Status	Score	Status	Score	Status	Score		Score	
Operational level	2		1		3		2		3		3		2				0
Tactical level	2		3		1		3		3		1		2				0
Sensor component	Coverage and data quality																
Significance	3						Status	Score	Status	Score	Status	Score	Status	Score		Score	
	Status			Score													
Psyops	2						3		3		1		1				0
CNO	2						3		2		3		3				0
EW	1						2		2		1		2				0
Land	2			3			2		3	2	3	2	1				54
Surface - Sea	2			2			2		1	2	2	2	1				30
Subsea	1						2		1		2		1				0
Air	2						3		1		2		2				0
Space	1						2		2		1		3				0
Effector component	Virkning																
Sigificance	3						Status	Score	Status	Score	Status	Score	Status	Score		Score	
	Status			Score													
Psyops	2						2		2		1		3				0
CNO	1						3		3		2		3				0
EW	3						3		2		2		1				0
Land	2						2		2		2		2				0
Surface - Sea	2						2		2		2		2				0
Subsea	1						2		3		2		2				0
Air	1						1		2		1		2				0
Space	0						0		0		0		0				0
Information Infrastructure (INI)	Connectivity and distribution capacity																
Significance	3						Status	Score	Status	Score	Status	Score	Status	Score		Score	
	Status			Score													
INI	2						1		3		2		2				0
															Total score		84

Figure 5: An experiment is evaluated and given different scores with respect to how the results may influence various properties and components.

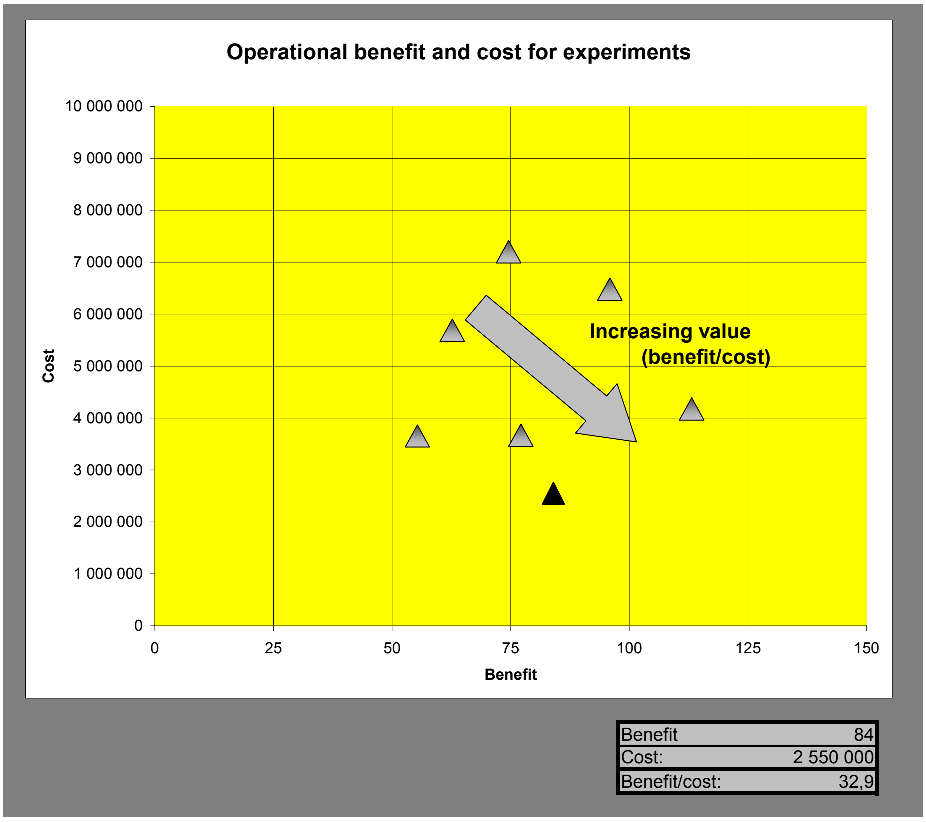

Figure 6: Presentation of benefit and cost and the calculation of the ratio of benefit of cost. The actual experiment under consideration (black) is compared to other experiments (shaded).

Web based process framework

Supporting the CD&E process and the prioritization of experiments a web tool has been developed. This tool guides and supports the decision maker through the assessment process. The start page of this web tool is shown in Figure 7.

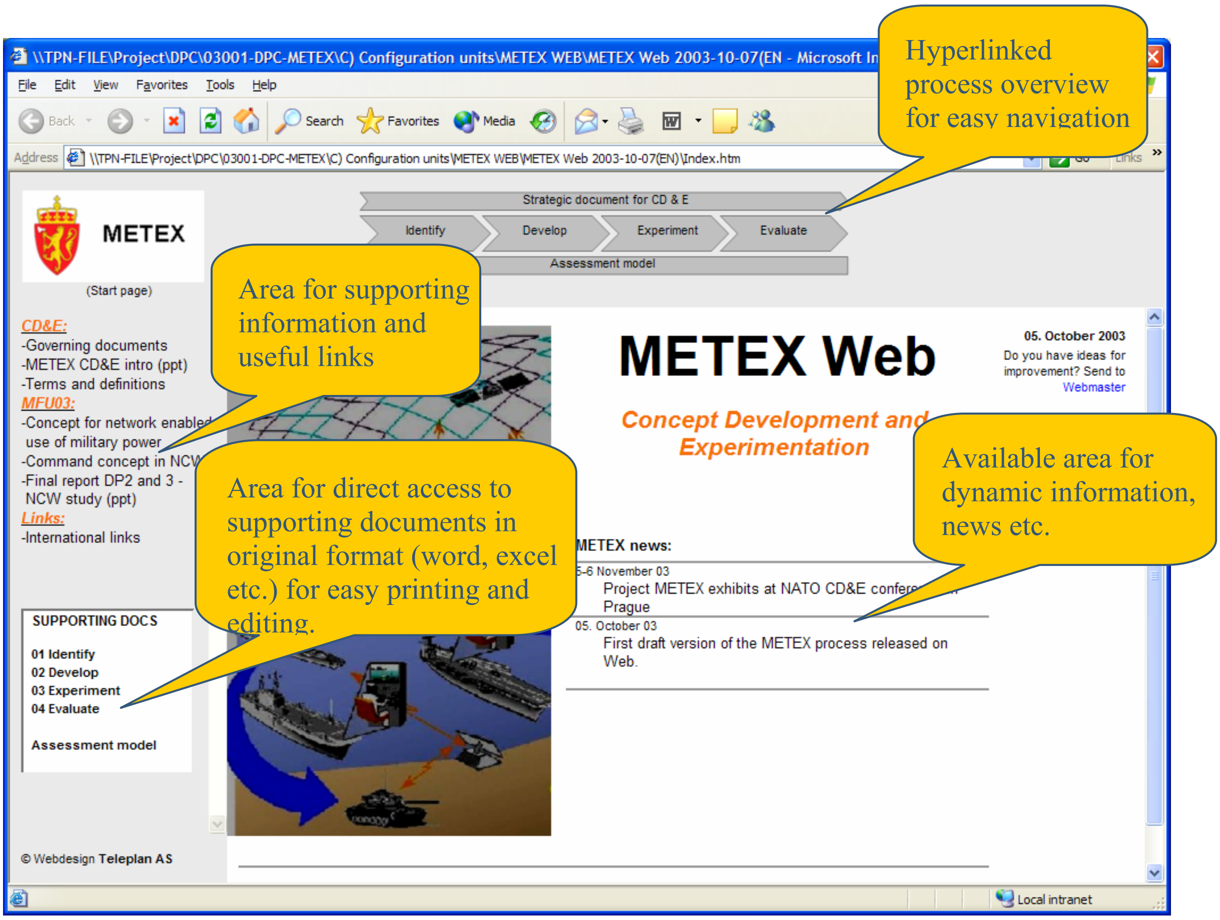

Figure 7: The start page of the METEX process web

Discussion

Some areas described above need some further elaboration and discussion. This is mainly related to the practical use of the models and tools. In particular, some considerations concerning the practical use of the assessment model should be appropriate.

The assessment model divides the military structure into components. The sensor and effector components have impacts in different operational environments. This is a point that has to be stressed for the decision makers using the model and for the experimental communities proposing experiments. For example, aircrafts in the role of close air support or as platforms delivering precision guided munitions against targets in the land environment contributes to the effector in the land environment.

The partition into operational and tactical levels for the decision component is a matter of temporal practical convenience, because initially we wanted to associate various headquarters and command posts with the decision component. This partition should be seen in a temporary context, because such a partition does not seem to support a network centric approach.

Also, the interfaces between components should be defined as rigorously as possible in the tool. For instance, the interface between the INI and the decision component must be defined with respect to information systems and information management.

It is also important that those who suggest experiments describe them so that it is easy to map the impact of the experiment into the assessment model. In the process web, there are templates that facilitate this description, so the impact on components and properties are correctly addressed.

The assessment model is primarily a decision support tool. In order to make qualified decisions, there must be a process of interaction between those who suggest experiments and the decision maker. The process web also facilitates this interaction. Using the process web helps the experimenter improve the design of an experiment, increase the operational value and reduce the costs.