Concept Maturity Levels
Bringing structure to the CD&E process

Wouter van der Wiel
TNO Defence, Security and Safety
The Hague, The Netherlands
wouter.vanderwiel@tno.nl

Ingrid Weima
TNO Defence, Security and Safety
The Hague, The Netherlands
ingrid.weima@tno.nl

Marcel-Paul Hasberg
TNO Defence, Security and Safety
The Hague, The Netherlands
marcel-paul.hasberg@tno.nl

Wim Huiskamp
TNO Defence, Security and Safety
The Hague, The Netherlands
wim.huiskamp@tno.nl

ABSTRACT

How does one structure, plan and cost a creative process that has inherent unstructured elements? Concept Development & Experimentation (CD&E) is a widely used term and methodology assisting transformation processes, research, and development. CD&E is such a creative process where a concept is developed through brainstorms, evaluation sessions and analyses combined with input from experiments. It leads to a robust concept that has been tried and tested in simulated experimental and operational settings, exposing aspects that could have been overlooked without experiments. But exactly this creative element brings uncertainty at the start of a CD&E process in terms of duration, cost and effort.

TNO Defence, Security and Safety has developed Concept Maturity Levels (CMLs) in order to provide a framework to structure the CD&E process, to communicate its status and progress, and to estimate the required level of effort and duration. We have worked with CMLs for more than a year now and they have proven very effective, for both internal and external communication about CD&E projects. In CML a six-level scale defines the maturity of a concept, providing structure, activities per level, and enabling the definition of a concept development roadmap at the beginning of the CD&E process.

ABOUT THE AUTHORS

Wouter van der Wiel is programme manager at TNO Defence, Security and Safety in The Netherlands. He coordinates CD&E methodology and infrastructure development.

Ingrid Weima is project manager at TNO Defence, Security and Safety in The Netherlands. Her research area includes concept development and facilitation techniques.

Marcel-Paul Hasberg is project manager at TNO Defence, Security and Safety in The Netherlands. His research area includes concept development and gaming.

Wim Huiskamp is chief scientist in the Modelling & Simulation and Gaming department at TNO Defence, Security and Safety in The Netherlands.

Concept Maturity Levels
Bringing structure to the CD&E process

Wouter van der Wiel
TNO Defence, Security and Safety
The Hague, The Netherlands
wouter.vanderwiel@tno.nl

Ingrid Weima
TNO Defence, Security and Safety
The Hague, The Netherlands
ingrid.weima@tno.nl

Marcel-Paul Hasberg
TNO Defence, Security and Safety
The Hague, The Netherlands
marcel-paul.hasberg@tno.nl

Wim Huiskamp
TNO Defence, Security and Safety
The Hague, The Netherlands
wim.huiskamp@tno.nl

INTRODUCTION

Current missions present the Armed Forces with urgent and diverse challenges, requiring fast development and effective adoption of new concepts such as C-IED (Counter – Improvised Explosive Devise) and NEC (Networked enabled Capability). Complex and urgent challenges, like the above, also need a method to experimentally develop or evolve capabilities. For instance, there is no clear-cut recipe for the implementation of NEC. The transformation 'from the industrial age to the information age' is a complex undertaking, both from an organisational and a technological point of view. The need for co-evolution of doctrine, command & control, training, organisation, processes, equipment and people – the so called lines of development – is generally acknowledged. Innovation is truly multi-technological and multi-disciplinary. The traditional means to design and assess the necessary innovations are often inadequate to deal with the complexity of the existing and future context. The approach known as 'Concept Development & Experimentation' or 'CD&E' is a powerful methodology to get to informed decisions on transformation challenges in Defence and Security and other areas.

CD&E is a widely used term and methodology assisting transformation processes. CD&E is a creative process where a concept is developed through brainstorms, evaluation sessions and analyses combined with input from experiments. It leads to a robust concept that has been tried and tested in simulated and operational settings, combining scientific and operational worlds and exposing aspects that could have been overlooked without experiments. But exactly this creative element brings uncertainty at the start of a CD&E process in terms of duration, cost and effort. How does one structure, plan and cost a creative process that has inherent unstructured elements?

The Netherlands research organisation TNO Defence, Security and Safety has developed Concept Maturity Levels (CML) in order to provide a framework to structure the CD&E process, to communicate its status and progress, and to estimate the required level of effort and duration. We have worked with CMLs for more than a year now and they have proven very effective, for both internal and external communication about CD&E projects. In CML a six-level scale defines the maturity of a concept, providing structure, activities per level and supporting the use of a concept development roadmap at the beginning of the CD&E process.

This paper presents the Concept Maturity Levels we developed as a missing link in structuring the CD&E process. It discusses its benefits and added value in the practice of the CD&E process and describes examples of its use.

WHAT IS CD&E ALL ABOUT

CD&E is about developing new concepts, by experiencing the challenges and developing and evaluating the new concept in a simulated setting before expensive resources are being acquired or before organisational changes are being implemented. It is important is to prevent the feeling: "If only I had known this and that beforehand then I would have done things differently."

These new concepts are always about capabilities, about creating a new capability or the improvement of an existing one. "*A capability supports the ability of an organisation to effectively realize its given or assumed objectives and missions*." The generic lifecycle of a capability has been described in, amongst others, [NATO GUIDEx] and [COBP Experimentation].

Thinking and doing are two more or less cyclical processes that subtly intertwine. By combining these two human capabilities, more intelligent solutions are possible and in closer reach. However, for an efficient group process, systematics and structure are needed. By creating a methodology for the combination of doing and thinking this structure and systematics are provided, enabling more effective group processes with several stakeholders in which a change of mindset is created and insight is developed. For an effective CD&E process it is important not to stay in one of the cycles too long. By thinking about what you want, what the best solution could be for a certain problem, the best way of finding out is by just doing it. In our opinion the methodology of CD&E must be based on this theory [TNO CD&E Guide].

The focus in a CD&E process is on the development of the concept by means of creating experiences and by experimenting as presented in figure 1. Another way of putting it is by Concept Development *through* Experimentation. With results of group brainstorms, evaluations, analyses and experiments a shared concept is developed, which describes the solution to the problem. Capturing the results, insights and decisions into a concept document leads to a robust concept that works as a guideline for the implementation of the solution or the improvement.

The concept is developed along multiple lines of development. The advantage is that the interdependencies of the development lines are recognized and incorporated right away. NATO uses DOTMLPFI as the lines of development: Doctrine, Organisation, Training, Materiel, Leadership, Personnel, Facilities, Interoperability.

In brief, CD&E is about:

- *Better solutions*: because realistic situations are experimented and user feedback is incorporated before the implementation of the final solution.
- *Creative solutions*: experiments form a creative environment for new ideas and solutions and CD&E creates a good mix of scientific and operational worlds.
- *Complete solutions*: influences of all lines of development are included and interoperability in complex environments is experimented and incorporated.

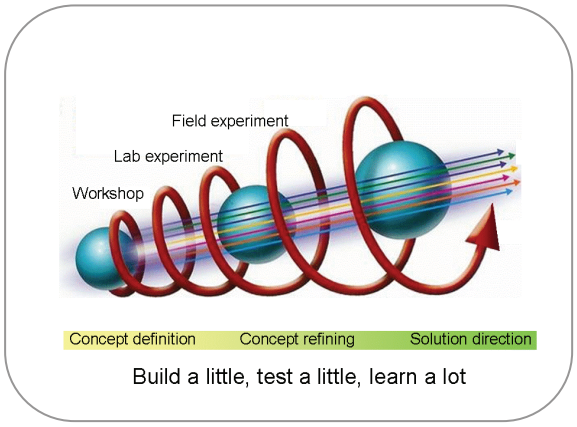

Figure 1 CD&E process (figure adapted from [BWB])

There is no accepted definition of CD&E as yet. We use the following working definition, which was translated and adapted from a proposal made by the German procurement office BWB [BWB]: "A *method which allows us to explore and predict, by way of experimentation, whether new concepts that may impact people, organisation, process and systems will contribute to transformation objectives and will fit in a larger context."*

DEFINITION OF A CONCEPT

The first question that comes up if one talks about concept development is: 'what is a concept?'. Even though this question is not the subject of this paper, it is relevant to have some agreement about the possible answer to this question.

NATO uses the following definition of a concept in the context of transformation processes: *"A notion or statement of an idea, expressing how something might be done or accomplished, that may lead to an accepted procedure."* [NSA].

In addition we define a concept as: *"A description of an idea shared by all stakeholders, which may enable improvement of an existing system, method, doctrine, an entirely new way of operating or a new capability."*

Usually concept development is complex because the relevant stakeholders are looking at a subject with different frames of reference. To develop a generic concept, the challenge is to let go of one's own reference and develop a common reference.

During the process of concept development a new awareness grows which brings the concept and the eventual capability to a new and higher level that will fit correctly in its environment.

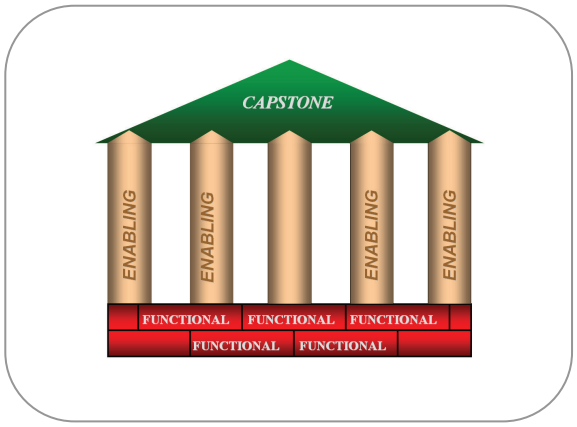

Figure 2 Concepts at the strategic, operational/ tactical and functional level [Wright Presentation]

Concepts can be directed at three different levels: *Capstone, Enabling* and *Functional* concepts as depicted in figure 2.

- *Capstone concepts* are strategic in nature. These describe the way an organisation intends to realize its strategic objectives in a general manner.
- *Enabling concepts* are aimed at the tactical/operational level. The outlines of various enabling concepts like fire support, infantry, engineers, etc., generally are clear. However, their organisational structures and their mutual interdependence need to be stated clearly.
- *Functional concepts* mostly describe systems or processes that support enabling concepts. As in the above-mentioned concepts, all DOTMLPFI factors and the mutual interdependence with related functional concepts need to be taken into account to allow for optimal integration.

HOW DOES CD&E WORK

The focus of CD&E is on the Concept Development. In a CD&E process a first concept-idea will be further developed, improved and refined by means of experimentation. This process continues until the new concept has been implemented and provides the desired capability. Each experimentation step is followed by a concept development step in which the concept is further completed, adjusted and refined on all of the selected lines of development. The steps may take from a week up to several years, depending on the level of detail and complexity of the concept.

In general, two kinds of activities can be identified in a CD&E process: the concept development activities and the experimentation activities. These are depicted in figure 3. Typical concept development activities are:

- *Brainstorming*: activities or group sessions in which new knowledge or ideas are being generated or related to each other.
- *Evaluation*: activities in which the outcomes of the brainstorms or experiments are being evaluated and translated to the concept.
- *Analysis:* analysis activities to support evaluation and concept definition.

The activities of concept development are constantly returning activities during a CD&E process. These activities are interleaved with experimentation activities. The concept will be tested in experiments, which will provide important input for the further development of the concept. We propose the following types of experimentation activities where it must be noted that other clusterings are possible.

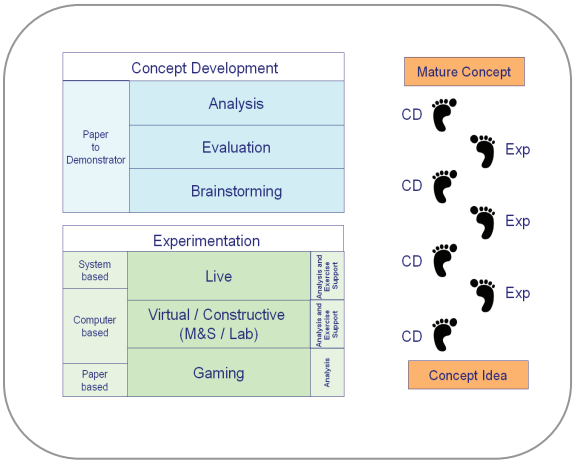

Figure 3 Concept development and experimentation activities in a CD&E process

- *Tabletop gaming:* these activities include mostly tabletop games using paper and/or computer supported games in which the person or persons that play the game play a central role.
- *Virtual & Constructive simulation:* these activities include computer-based experiments where the focus lies on investigating the detailed behaviour of a modelled system that represents the concept. Constructive simulations use models of both the systems and the operator's behaviour, whereas Virtual simulations use human operators and simulated systems and environments.
- *Live:* these activities include all experiments with a real system in the field, using operational

software and hardware, including operators, in a suitable live test environment.

The concept development and the experimentation activities are supported by particular tools and methods. Not all activities are necessarily carried out in every CD&E process. The development of a concept starts with an initial concept idea, mostly on one line of development, for example the materiel line of development, see figure 4. It starts from either a problem or capability gap, or from a new opportunity or new technology. The lines of development are defined and the concept grows to include all. It is important that the concept matures along all the determined lines of development already in the early phases of the CD&E process until the concept can be demonstrated in a relevant operational setting. During the development, the concept will be tested in experiments, including some or all lines of development. These will provide important input for the further development of the concept. This is the iterative part of CD&E. The final evaluation of the steps of a CD&E process results in an evidence-based recommendation with respect to the proposed new concept. The concept has now matured and is ready for implementation.

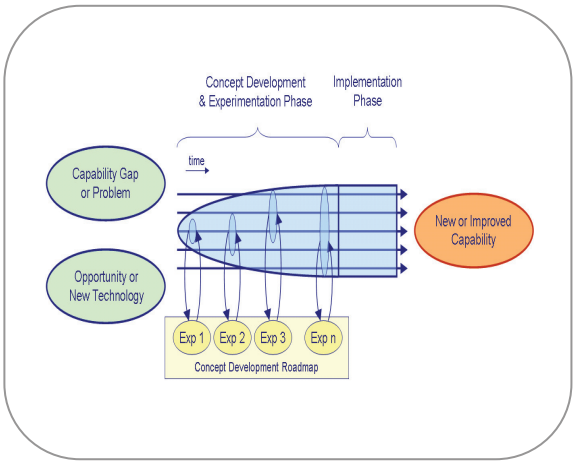

Figure 4 An interactive process of concept development by means of experimentation

The process of developing new concepts, for example for organisations like the Armed Forces, often involves many stakeholders. During all the several activities of the CD&E process it is of the utmost importance to involve the right people (functions) to make the new concept work. This adds to the complexity of organising the CD&E process.

THE MISSING LINK

CD&E is a fairly complex process with several different types of activities and the involvement of many stakeholders. The difficulties we encountered in CD&E projects were threefold:

- *Communication on progress*: for a concept under development, the communication on progress was difficult. Experiments could be evaluated and communicated, but a common reference for the status of the concept was missing. This was obvious for internal communication between different teams and specialists, and also for external communication to the customer or sponsor. This is a crucial part in achieving success and preventing shifting expectations.
- *Interactions between CD&E activities*: the interactions of concept development activities and experimentation activities were not clear and as well developed and planned as needed. Different teams were working with different frameworks, which made it harder to achieve good coordinated results. Expectations and results from activities can be better aligned when using a common reference.
- *Scheduling and costing CD&E projects*: in agreements with customers or sponsors it was difficult to define what the end result of a CD&E project should be for a given budget. Defining a number of experiments for a fixed budget is easier to do, but that leaves the status of the resulting concept unclear and thus also its value. Also, not all concepts have to be developed into a capability at once. With a framework it is possible to group certain stages of the process and define results per stage in terms of the maturity of the concept.

These three difficulties resulted in a CD&E process where the focus was largely on experimentation, while the end result should be a well developed and broadly accepted concept. The missing link is a framework to structure the CD&E process that focuses on the concept, defines the different development stages and allows for easy communication.

STRUCTURING THE CD&E PROCESS WITH CMLs

The framework to structure the development of a concept is based on the idea of Concept Maturity Levels (CML). The CML will indicate the maturity of a concept using a six-level scale each indicating an important milestone in the process of developing a concept.

With these milestones it is possible to indicate and estimate how much and what kind of effort is needed to develop a concept up to the desired level. The CMLs are presented in figure 5, and described below. During all levels the concept document has a central role in recording all the input and output of the activities being explored. This concept document also serves as a (social) contract between the stakeholders in the process.

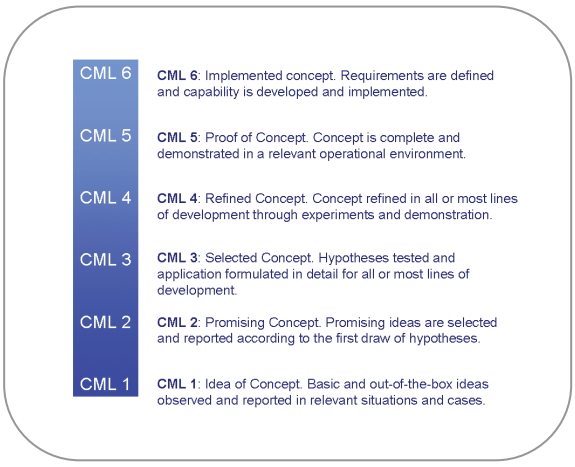

Figure 5 Six-level scale of Concept Maturity Levels to provide a framework to structure the CD&E process

Concept Maturity Level 1 – Idea of Concept: Basic and out-of-the-box ideas observed and reported in relevant situations and cases: The first level of maturity is reached when all starting points for possible solutions and improvements are on the table, the so called ideas of concepts. These ideas are creative and out-of-the-box, but relevant in the situations and cases for the problem. The different ideas are clustered or related to each other to get an idea of the different directions of the solutions that are presented. To start the brainstorm of the ideas of concept it is necessary to have insight in the problem situation, the challenges and dilemmas. Also the criteria for the further concept selection are defined in this setting. At the end of level 1 all ideas of concept, the problem situation and criteria are documented in the concept paper.

Concept Maturity Level 2 – Promising Concept: Promising ideas are selected and reported according to the first draw of hypotheses: The second level of maturity is reached when a selection has been made of promising ideas of concepts. This selection is made on the basis of criteria in the form of hypotheses which are formulated at this stage. These hypotheses have a relation with the selected lines of development on which the concept is being developed. At the end of level 2 the selection process has been documented and the promising concepts are described on a few selected lines of development.

Concept Maturity Level 3 – Selected Concept: Hypotheses tested and application formulated in detail for all or most lines of development: The third level of maturity is reached when one concept is selected as the best possible solution. At this point all the selected lines of development have been reviewed for the promising concepts, and one concept or a combination is selected. At the end of level 3 the selected concept is described in the concept document as well as the selection process leading to it.

Concept Maturity Level 4 – Refined Concept: Concept refined in all or most lines of development through experiments and demonstration: The fourth maturity level is reached when the selected concept is refined in more detail on the selected lines of development. These refinements are done by different concept development and experimentation activities and, very important, with all stakeholders involved. At the end of level 4 the concept is described on all lines of development.

Concept Maturity Level 5 – Proof of Concept: Concept is complete and demonstrated in a relevant operational environment: The fifth level of maturity is reached when important parts or the total concept are demonstrated in a relevant operational setting, being virtual or live. The concept has proven itself as the solution for the problem or as a significant improvement over the old situation. The concept is ready for implementation in the organisation or the system for which it has been developed. At the end of level 5 the results of the demonstration are described as well as how the concept has proven to work. At this point the concept document is finished.

Concept Maturity Level 6 – Implemented Concept: Requirements defined and capability is developed and implemented: The highest level of maturity we have identified is somewhat obscure in the process of CD&E. It is about the implemented concept or implemented solution. We do not articulate this process of implementation specifically, but we want to stress that CD&E is always done to develop a solution or capability. The concept document forms the basis for final requirements development and implementation.

WHY THESE LEVELS

Why develop a new framework and not use an existing one such as the Technology Readiness Levels (TRL), Capability Maturity Model (CMM) or the NATO Networked Enabled Capability (NEC) maturity levels.

Working with concepts, we experienced that as long as they are of a technical nature, TRLs can be used, but as soon as a concept is about an organisation or a doctrine, they were no longer applicable. Since CD&E is about developing capabilities the CMM sounds like a good match. However, CMM is closely linked with software development and defines the maturity of the organisation or process developing the product and not so much of the actual product itself. The NATO NEC maturity model deals mainly with Command and Control (C2) and is not very applicable to other concepts.

Innovative concepts are not only multi-technological but also multi-disciplinary. So to meet our needs, we set up a framework to focus as much as possible on the maturity of the concept working in a multi-disciplinary environment. The CMLs express the co-evolution of an idea to a mature and tested solution working on multiple lines of development.

NASA [Vane] had recognised a similar gap in expressing maturity between (mission) concepts and technology (with TRL). The CMLs designed by TNO focus specifically on the multi-disciplinary development of the concept, while the NASA CMLs focus more on the system engineering process. We are in contact with NASA about the CMLs and will continue to refine our framework for CD&E.

BENEFITS AND ADDED VALUE OF INTRODUCING CMLs

Introducing the CMLs provided us with a fitting answer to the difficulties we encountered in CD&E projects.

The CML framework provides different stages in the concept development process, which make it easier to communicate on the progress and status of the concept under development.

The next step was to define activities per CML, which made it possible to lay out a concept development roadmap, see figure 6, showing planned activities for a project for each CML. The concept development roadmap is built based on the activities best suited for a particular concept. This improved internal communication and coordination between the different CD&E activities.

Scheduling and costing of CD&E projects was also improved by using the CMLs and the concept development roadmap. Results and activities can be defined in terms of concept maturity, and agreements can now be made per group of CML, in stead of for a whole concept or a series of experiments. This gives the link between CD&E activities and the status of the concept, i.e., the result. Next to that, the roadmap forms a useful guideline aiding the CD&E project management and allows for more natural go/no-go decision moments.

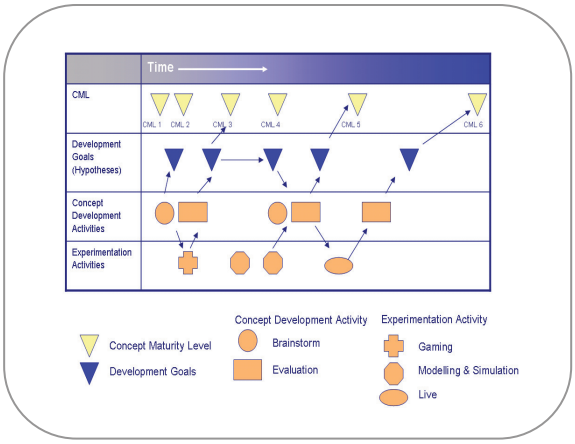

Figure 6 Concept Development Roadmap (inspired by [NATO GUIDEx])

EXAMPLES

Described below are two examples of the benefits and added value of CMLs in CD&E projects at TNO.

UGVs for Afghanistan

Based on recent experiences of the Royal Netherlands Army (RNLA) in Afghanistan, the need for more types of unmanned ground vehicles (UGV) was recognised. Initial plans were to purchase 3 types of UGV for immediate experimentation.

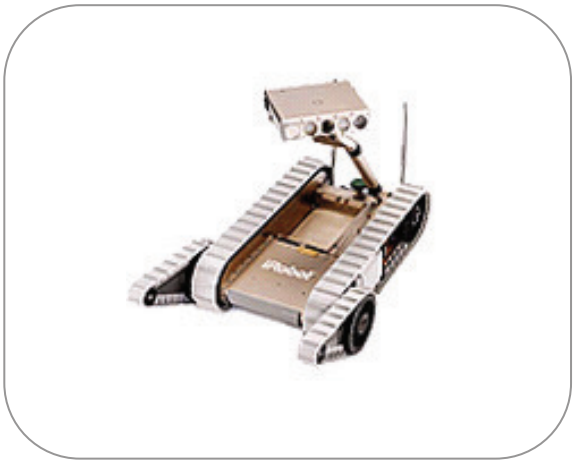

Figure 7 Unmanned Ground Vehicle (Packbot Explorer)

CD&E was selected as the approach to develop the concept for UGVs operations of the dull, dirty and dangerous tasks.

In communications between TNO and the RNLA, the CMLs turned out to be very useful in understanding and structuring the necessary process. Early in the CD&E process a concept development roadmap was made including the decision to work with brainstorms and analyses to achieve CML 1 and CML 2, and only after that, introduce the live UGVs for experimentation.

In the activities leading to the first level of maturity, the RNLA mission requirements and needs for various types of operations using UGVs were defined. When CML 2 was reached, the concept description was matured to a point where it was already clear that only 2 of the 3 types of UGV were suited for the required operations. The investment in the third type was not necessary anymore and the money was saved.

This was a very clear case where the additional structure of CMLs helped in agreements on the type of activities leading to a better result.

GBADS TTPs

With the introduction of a new ground-based air defence system (GBADS), the Royal Netherlands Army (RNLA) also introduced a new concept of operations, and expressed the need for a new training system. GBADS will include a chain of operation centres (radar), Shorad fire-control stations (launchers), BMC4I staff, platoon staff and/or battery staff. The question was: How to operate the new networked Air Defence System and how to develop new Tactics, Techniques and Procedures (TTPs) through experimentation?

CD&E was selected by the RNLA as an approach to facilitate the transformation process for GBADS and obtain experimental evidence on the suitability of proposed innovations to meet the needed military capabilities. TNO facilitated the RNLA's process of defining the new concept and in the subsequent requirements definition of the training system and method of training. Using the CMLs a clear process could be designed inline with the acquisition process of the RNLA GBAD system. Subsequently, concept development and experimentation activities were planned, and the decision was made to follow the CD&E approach of low-high fidelity experiments, stepping through the CMLs.

Figure 8 GBADS Assets

Initial brainstorm sessions were used to generate ideas for the GBADS concept. The Tactics, Techniques and Procedures for GBADS were then defined in a document paper by a RNLA team of subject matter experts (CML 1 and 2). The selected concept was subsequently refined and iteratively adapted, based on experimental results from simulated runs. During this process, not only the concept of operation and the requirements for the systems became clear, but also the subject matter experts way of thinking about their concept of operation evolved. By then, concept maturity level 3 and 4 were reached and all involved stakeholders were inline with each other and spoke the same language.

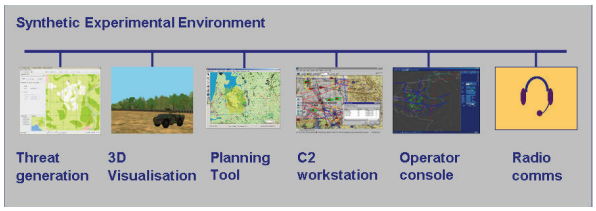

Figure 9 GBADS Synthetic Environment

The experimentation environment was composed using existing simulation models. The assets included threat generation (JROADS), air defence systems and operator consoles (JROADS), the RNLA operational C2 systems (ISIS), and several support and planning tools. Simulated voice radio communication networks were provided with similar functions as in the real environment.

Figure 10 Exercise Briefing before Experiments

Initial simulated runs with operational users in a laboratory setting were followed by participation in large-scale field experiments including other simulations and live equipment. These experiments and demonstrations were conducted in the context of the Joint Project Optic Windmill (JPOW) series. After these experiments, concept maturity level 5 was reached and the proof of concept was delivered.

The capability for iterative refinement of system concepts and operational concepts is one of the "strong-points" of CD&E. The GBADS experiment helped, not only to get the systems right, but also to get the "thinking" right. Active user involvement right from the beginning is important for user acceptance.

CONCLUSIONS

The proposed Concept Maturity Levels have clearly brought structure to the process in our CD&E projects. This framework provided us with a reference to communicate on the progress of the concept development, being able to plan the interaction between the different activities over time, and define the desired (end) state of the concept together with the customer or sponsor. The concept development work can now be split up in different stages, which are better defined, better understood and more manageable. This is aided by the use of the concept development roadmap in ordering the best suited activities for a concept over time. We have seen that the focus in CD&E is slowly starting to shift from experiments to the concept. This was one of the aims we had for introducing the CMLs.

The CML approach described in this paper allows MoD, industry and research organisations to work together using a common reference framework that provides the necessary structure to manage the CD&E process. The 'best practices' for CD&E are still being developed and refined with every case. The CML approach is an example of these best practices that will provide more effective use of CD&E in future projects.

ACKNOWLEDGEMENTS

The authors would like to thank all involved in the development of the CD&E vision and CMLs in the Netherlands.

REFERENCES

- [NATO GUIDEx], Guide for Understanding and Implementing Defense Experimentation, TTCP (The Technical Cooperation Program), February 2006;http://www.dtic.mil/ttcp/GUIDExPocketbook Mar2006.pdf
- [COBP Experimentation], Code Of Best Practice Experimentation], D.S. Alberts, CCRP (Command and Control Research Program), July 2002
- [TNO CD&E Guide] Guide for doing and understanding CD&E, TNO Defence, Security and Safety, July 2010
- [BWB], Bundesamt für Wehrtechnik und Beschaffung (BWB), http://www.bwb.org
- [NSA], NATO glossary of terms and definitions (AAP-6), NATO Standardization Agency (NSA), March 2010
- [Wright Presentation], NATO Concept Development & Experimentation Overview (presentation at NATO CD&E Conference 2008), Lt Col J. Wright, JEEA HQ SACT, November 2008
- [Vane], http://www.spacepolicyonline.com/ pages/images/stories/JPL_re_Concept_Maturity_Level_Nomenclature.pdf, July 2009