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Virtual air mission definition phase

S&T support to Air Force CD&E

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Defence R&D Canada – Valcartier
Technical Report
DRDC Valcartier TR 2006-003
September 2008

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Abstract

A Definition Phase was mandated to Defence R&D Canada – Valcartier (DRDC Valcartier) by the Director Science and Technology Air (DSTA) in order to better define the Air Force needs in terms of Modelling and Simulation (M&S) support from the DRDC Science and Technology (S&T) organization. The mandate was specially oriented toward supporting a new organization called the Canadian Air Force Aerospace Warfare Centre (CFAWC). The definition phase revealed that air warfare Concept Development and Experimentation (CD&E) is far from having reached the level of maturation needed to adopt definitive process and technologies for S&T support to CD&E. It is thus envisioned that the required technology would be developed and implemented during follow-on research projects aligned on a coherent S&T strategic plan. It is believed that the S&T community must focus on improving the CD&E process and infrastructure through a series of pilot studies. These realistic applications will help to develop how S&T will continue to support specific on-going CD&E campaigns. The overall S&T contribution will lead to a seamless process and a persistent infrastructure for air warfare CD&E.

Résumé

Le Directeur – Science et technologie (Air) (DSTA) a confié à R&D pour la défense Canada – Valcartier (RDDC Valcartier) le mandat d'effectuer une phase définition afin de mieux cerner les besoins de la Force aérienne en matière de soutien en modélisation et simulation (M & S) de la part de la communauté de science et technologie (S & T) de RDDC. Le mandat a été particulièrement orienté vers le soutien d'une nouvelle organisation appelée le Centre de guerre aérospatiale des Forces canadiennes (CGAFC). La phase de définition a indiqué que l'évaluation et l’expérimentation de concepts (ECC) de la Force aérienne est loin d'avoir atteint le niveau de maturité requis pour adopter un processus et des technologies définitifs pour l'appui de la S & T à l'EEC. On s’attend à ce que les technologies requises soient mises en application durant de futurs projets de recherche selon un plan stratégique cohérent. On a établi que la communauté de S & T devrait se concentrer sur l’amélioration du processus et de l’infrastructure pour l’EEC au moyen d’une série de projets pilotes. Ces applications réalistes aideront à déterminer comment la S & T appuiera les campagnes opérationnelles d’ECC. L’ensemble de la contribution mènera à un processus intégré et à une infrastructure persistante pour l’ECC dans la Force aérienne.

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Executive summary

The Virtual Air Mission (VAM) project aims at developing an infrastructure based on a Synthetic Environment (SE) that would allow the efficient use of Science and Technology (S&T) to support the whole range of Canadian Air Force (AF) virtual life cycle activities. A Definition Phase has been mandated to Defence R&D Canada – Valcartier (DRDC Valcartier) by the Director Science and Technology Air (DSTA) in order to better define the AF needs in terms of Modelling and Simulation (M&S) support from the DRDC S&T organization. The mandate was specially oriented toward supporting a new organization called the Canadian Air Force Aerospace Warfare Centre (CFAWC). CFAWC being currently in its definition phase, it was timely to describe how the Science and Technology (S&T) community can support AF CD&E and M&S activities.

The definition phase revealed that air warfare CD&E is far from having reached the level of maturation needed to adopt definitive formal process and technologies for S&T support to CD&E. It is thus envisioned that the required technology would be implemented during follow-on research projects. Therefore, the phase resulted in defining a work plan to develop the building block of a complete and formal S&T support to CD&E. This will ensure that the chosen approach is appropriate and adapted to the evolving CFAWC.

It is believed that the S&T community must focus on improving the maturity of the CD&E process. A CD&E maturity model could be derived accordingly by defining and implementing the best practices necessary to achieve progressively higher maturity levels. The proposed research projects will directly contribute to this objective through a series of pilot studies using realistic CD&E campaigns to address:

- the role of M&S in CD&E;
- the appropriate level of M&S for CD&E;
- the capability engineering applied to CD&E;
- the transition of S&T expertise during concept development; and
- the development of a complete synthetic environment infrastructure including a simulation framework, analysis tools, a network, a collaboration portal, a resource repository and an expertise directory.

The overall S&T contribution will lead to a seamless process and a persistent infrastructure for air warfare CD&E. The S&T deliverables could also become building blocks for the global Air Force synthetic environment to achieve the original VAM project vision.

Harrison, N. and Lestage, R. 2008. Virtual Air Mission Definition Phase: S&T support to Air Force CD&E. DRDC Valcartier TR 2006-003 Defence R & D Canada - Valcartier.

Sommaire

Le projet de mission aérienne virtuelle a pour but de développer une infrastructure basée sur un environnement synthétique qui permettrait l'utilisation efficace de la science et technologie (S & T) à l'appui de la gamme entière des activités du cycle de vie de la Force aérienne. Le Directeur – Science et technologie (Air) (DSTA) a confié à R&D pour la défense Canada – Valcartier (RDDC Valcartier) le mandat d'effectuer une phase définition afin de mieux cerner les besoins de la Force aérienne en matière de soutien en modélisation et simulation (M & S) de la part de la communauté de S & T de RDDC. Le mandat a été particulièrement orienté vers le soutien d'une nouvelle organisation appelée le Centre de guerre aérospatiale des Forces canadiennes (CGAFC). CGAFC étant actuellement dans sa phase de définition, il était opportun de décrire comment la communauté de S & T peut soutenir ses activités d'élaboration et d'expérimentation de concepts (EEC) et de M & S.

La phase de définition a indiqué que l'EEC de la Force aérienne était loin d'avoir atteint le niveau de maturité requis pour adopter un processus et des technologies formels et définitifs pour l'appui de la S & T à l'EEC. On envisage donc que les technologies exigées soient mises en application lors de futurs projets de recherche. Par conséquent, la phase de définition a résulté en un plan de travail pour développer les éléments d'un soutien complet et formel de la S & T à l'EEC. Ceci assurera que l'approche choisie est appropriée et adaptée au CGAFC au fil de son évolution.

On a établi que la communauté de S & T devait se concentrer sur l’amélioration du niveau de maturité du processus pour l’EEC. Un modèle caractérisant la maturité de l’EEC pourrait être déduit en définissant et en implantant les bonnes pratiques nécessaires à l’atteinte progressive de niveaux de maturité supérieurs. Les projets de recherche proposés contribueront directement à cet objectif au moyen d’une série d’études pilotes basées sur des applications réalistes d’EEC et portant sur:

- le rôle de la M & S dans l'EEC;
- le niveau approprié de M&S en soutien à l’EEC;
- l’ingénierie de concepts appliquée à l’EEC;
- le transfert d’expertise en S & T durant le développement de concepts; et
- le développement d’un environnement synthétique complet incluant une architecture de simulation, des outils d’analyse, un réseau, un portail collaboratif, une base de données de ressources et un répertoire d’expertise.

L’ensemble de la contribution mènera à un processus intégré et à une infrastructure persistante pour l’EEC dans la Force aérienne. Les livrables de la S & T pourront également devenir des éléments de base pour l’environnement synthétique global de la Force aérienne afin de réaliser la vision d’origine du projet de mission aérienne virtuelle.

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1. Introduction

The Virtual Air Mission (VAM) Applied Research Project aims at developing an infrastructure based on a Synthetic Environment (SE) that would allow the efficient use of Science and Technology (S&T) to support the whole range of Canadian Air Force (AF) virtual life cycle activities, as illustrated in Figure 1.

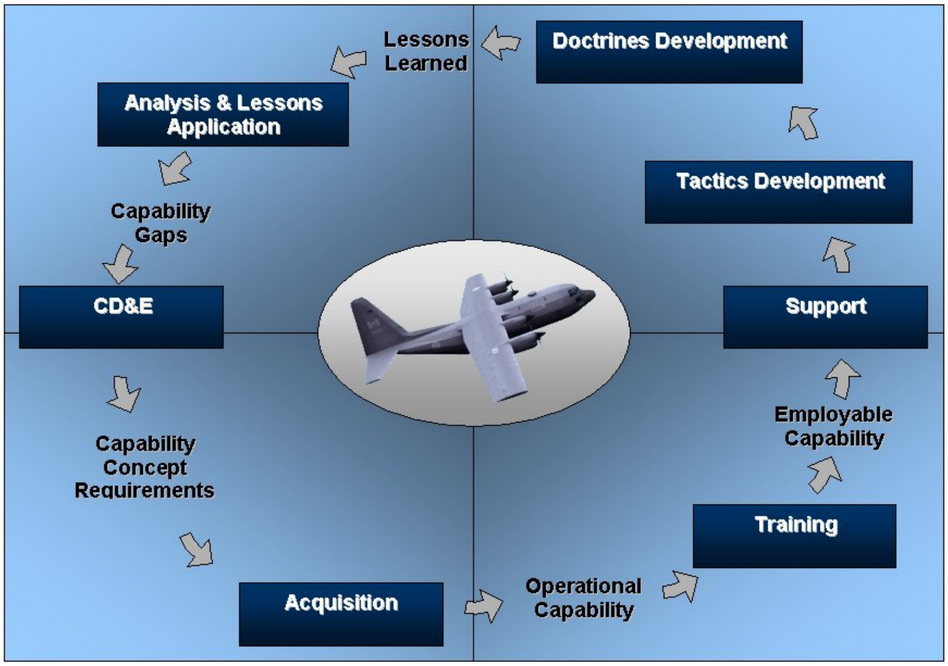

Figure 1. The virtual life cycle

Of course, the VAM must be conducted to specifically meet the AF requirements and in coordination with other initiatives of the Department of National Defence (DND) such as the Joint Simulation and Modelling for Acquisition, Rehearsal, Training and Support (JSMARTS) led by ADM(Mat). Whatever the life cycle phase prioritized by the VAM Project, the contribution can be leveraged to the other activities if coordination, commonality and interoperability are well established. It is envisaged that the Canadian Advanced Synthetic Environment (CASE) [1], led by the Air Force, will be used as the principal interaction mechanism for the conduct of virtual life cycle activities.

1.1 Mandate context

A Definition Phase has been mandated to Defence R&D Canada – Valcartier (DRDC Valcartier) by the Director Science and Technology Air (DSTA) in order to better define the AF needs in terms of Modelling and Simulation (M&S) support from the DRDC S&T organization.

Concept Development and Experimentation (CD&E) has been identified as an enabler to AF transformation [2, 3]. M&S, Synthetic Environments (SE) and networked systems are enablers to achieve cost-effective integration and collaboration inherent to the multidisciplinary applications of CD&E. Therefore, the AF transformation strategy includes the creation of a new organization to conduct AF CD&E and to coordinate AF M&S. This organization is called the Canadian Air Force Aerospace Warfare Centre (CFAWC) [4, 5]. CFAWC being currently in its definition phase, it was timely to describe how the Science and Technology (S&T) community can support AF CD&E and M&S activities. This work relates to the Analysis Phase of the virtual life cycle shown in Figure 1.

The Definition Phase was mandated in the perspective of Research and Development (R&D) [6]. One major change is to systematically align deliverables to strategic planning needs. The usual continuous innovation, which is technology-pushed, is then replaced by discontinuous innovation, which is capability driven. Mastering this linkage between strategy, innovation and R&D fosters the Canadian Forces transformation [7].

1.2 Project description

The objective of this VAM Project Definition Phase is to establish a process to provide S&T support to air warfare CD&E. The Project intends to establish a proactive way of interaction in order to better tailor R&D efforts to Air Force requirements and to build a common Virtual Air Mission environment over a long-term collaboration.

The outcome of the definition phase is a proposal on the methodology to provide air warfare CD&E S&T support and a roadmap for developing future air warfare CD&E technology. The deliverables are this report describing the concept of a generic process for S&T air warfare CD&E support and a follow-on Applied Research Project (ARP) proposal to provide CD&E support for the AF.

This project addresses the question of S&T support to CD&E in an innovative way. S&T projects usually either directly support on-going CD&E applications or the definition of CD&E processes themselves. This project focuses on the process of formal interactions to transition S&T expertise to better support CD&E activities. This aspect of CD&E is scarcely detailed in existing CD&E processes. The Project will focus on how to leverage engineering-level knowledge to evaluate its potential benefits on future capabilities. Although electro-optical warfare and precision weapon experts from DRDC Valcartier conducted the Project, the results are applicable to any DRDC activity.

1.3 Strategy for conducting the mandate

The first part of DRDC Valcartier’s strategy was to collect the clients’ requirements. The clients identified were CFAWC, the Director of Aerospace Requirements (DAR) and the Directorate of Air Strategic Plans (D Air SP). A first meeting with the client aimed at aligning our different points of view on the subject of S&T support to AF

CD&E activities and to ensure that the actions planned during the definition phase meet the Air Force needs. During this meeting, the real concerns of the client were identified as well as the status of implementation of CFAWC. A second meeting was conducted to present an analysis of what CFAWC's CD&E role is likely to be and to discuss how the links between S&T and CD&E might happen within the proposed process and supporting technology proposals.

The second part of the strategy was to perform an analysis of S&T support to CD&E and to collect data and lessons learned from similar initiatives. To complement its perspective, DRDC Valcartier awarded a contract to Greenley and Associates Inc. (G&A) to provide an independent analysis of S&T support to AF CD&E [8]. Both of DRDC Valcartier's and the contractor's perspectives are formulated as process and supporting technology proposals.

The third part of the strategy was to ensure coordination with the other communities. It was achieved by presenting the process options and supporting technology proposals in a paper to the NATO Modelling and Simulation Conference 2004 [9] and to the JSMARTS Vision Workshop [10].

The last part of the strategy is the validation of the proposals against the clients' needs. The results from DRDC Valcartier and the independent contractor are analyzed and merged according to client comments in order to generate the best combined solution to provide S&T support for the conduct of CD&E activities. The solutions will be aligned with existing DND strategy and projects such as ADM(Mat) JSMARTS initiative and the DAR 7 CASE project.

The first section introduced the mandate and the strategy to conduct the project. The next chapter presents the CD&E and S&T perspectives. Chapter 3 contains DRDC Valcartier's analysis of S&T support to CD&E while Chapter 4 describes the requirements and the supporting state-of-the-art technology for S&T interaction with CD&E. Chapter 5 includes the compilation of validation results as well as the additional considerations arising from the contractor's and the client's input. Chapter 6 suggests a work plan for the implementation and maturing of the proposed support. Finally, the concluding section summarizes the selected approach and proposes a way ahead for the project.

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2. Understanding CD&E and S&T perspectives

Prior to identifying S&T contributions to CD&E, it is important to understand the responsibility of each player. Therefore, this chapter introduces what is CD&E as well as the role of S&T with respect to CD&E. The last chapter also raises CFAWC's perspective on the subject of S&T support to AF CD&E. The role of M&S and SE is also addressed.

2.1 What is CD&E?

In the defence context, a military concept refers to operating concepts, which describe how military forces operate, and to functional concepts, which describe the performance of individual military functions or sub-functions [11]. CD&E is defined as the application of the structure and methods of experimental science with the aim of exploring innovative methods of operation, especially to assess their feasibility, evaluate their utility, or determine their limits [12]. CD&E helps to achieve the revolution of military affairs through capability-based planning [6]. The development and experimentation of new concepts is specifically oriented to fill capability gaps.

Several CD&E organizations in different countries have their own process more or less similar to others. As an example, Figure 2 illustrates a generic CD&E process proposed by Alberts et al. [13]. The process assumes that capability gaps have been defined a priori. It starts by a discovery experiment to evaluate the concept potential. If there is potential, the concept is further developed through research and development activities directed by the findings of experimentation cycles that refined the preliminary hypothesis. The concept can eventually be transferred to the activity following the CD&E: the acquisition and implementation of the capability.

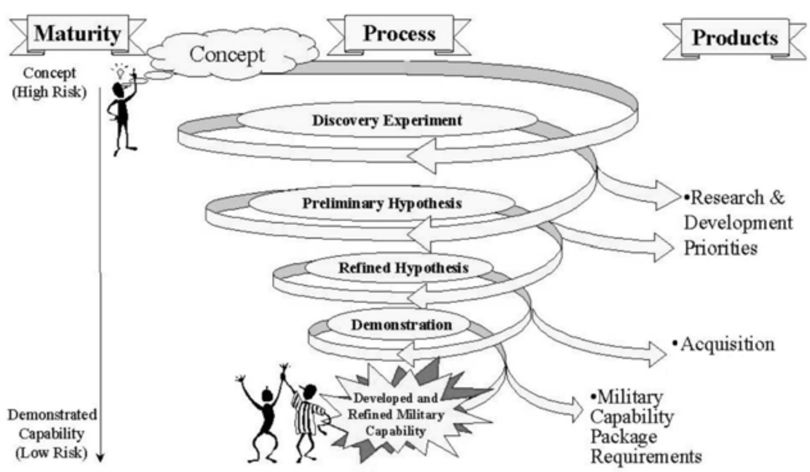

Figure 2. Illustration of a generic CD&E process [13]

As shown in Figure 3, CFAWC drafted a possible implementation of the CD&E process. The concept development phase consists of the concept description using idea inputs. Next, an experimentation plan (or strategy) further develops the concept. The experimentation plan is then devised and the experimentations are conducted through iterative design, preparation, execution and assessment steps. The conclusions are reported to an integrating authority responsible for the implementation of a new or improved capability. Except for the potential source of a concept, this CD&E process does not point out any explicit interaction with the S&T contributors.

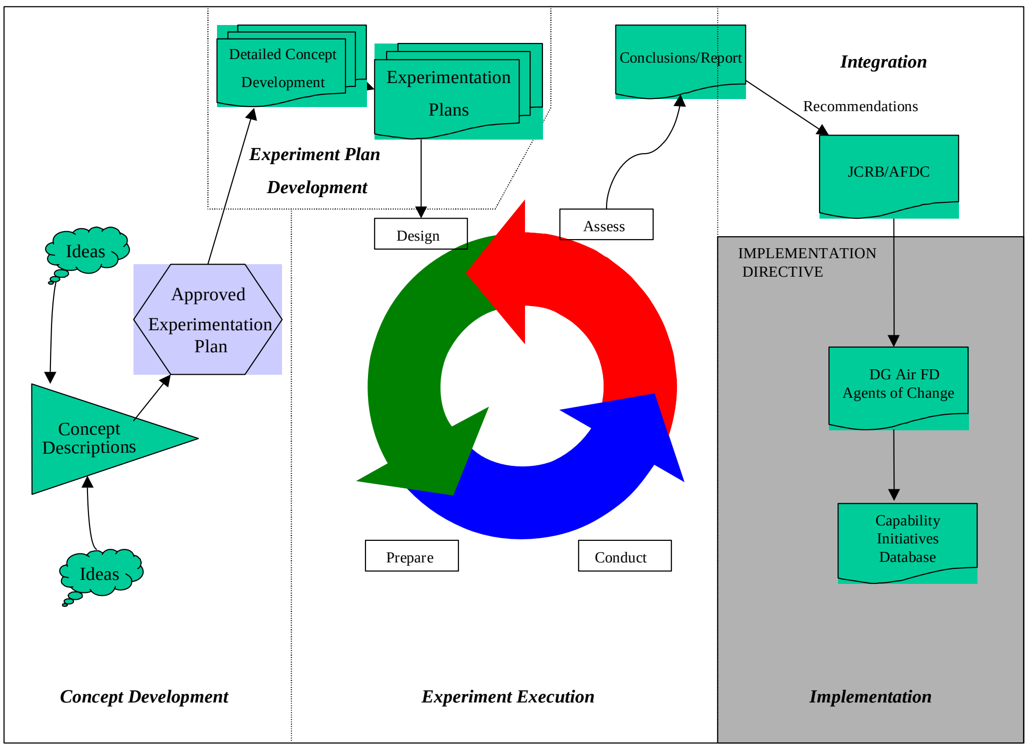

Figure 3. CFAWC's draft implementation of a CD&E process [5]

M&S is frequently referenced in CD&E since, among all CD&E techniques, it allows the participation of CD&E in the virtual life cycle illustrated in Figure 1. In the Canadian context, the CD&E and M&S coordination organizations were created purposely to follow the recommendation for systematically applying M&S to CD&E [14, 15, 16].

2.2 Role of S&T

The S&T community is an important player in CD&E as a source of innovative concepts and technological advances.

The S&T community is composed of two main groups of scientists. The R&D scientists who investigate and develop technologies for military purposes and the Operational Research (OR) scientists who apply the scientific method to military problems. To provide expert advice, objective research and analytical support to military client, OR draws on multiple scientific disciplines and analytical techniques [4].

While the conduct of operational research is usually carried out in close relation with military needs and personnel, R&D is performed with a longer horizon and thus at a slower pace.

In the M&S world, the defence technology experts are called Subject Matter Experts (SMEs). They are individuals who, by virtue of position, education, training, or experience, are expected to have uncommon expertise or insight relative to a particular technical or operational discipline, system, or process. They have been selected or appointed to participate in the development, Verification,Validation and Accreditation (VV&A), or use of a model or simulation [17]. However, in the military context, SMEs often refer to military personnel with expertise in a specific aspect of military analysis. In the context of the current project, Science and Technology Subject Matter Expert (S&T SME) will refer to technical SMEs who are doing R&D within S&T organizations, as opposed to operational SMEs who are military operation experts. For example, engineering-level S&T SMEs could be specialists of precision weapons or electro-optical warfare sub-systems.

2.3 CFAWC's perspective

The current research is conducted from the perspective of engineering-level M&S S&T SMEs. The first meeting with the clients revealed a different perspective. Their real concerns on the subject of S&T support to CD&E are listed below.

- The main mandate of a CD&E organization is to enable a capability by defining and evaluate concepts and its work must lead to concept implementation, whatever the means or technique used to achieve it.

- Because of the limited resources to perform the main mandate, the level of involvement into related domains, such as capability requirements and M&S, must be prioritized.

- From the CD&E perspective, M&S is essentially a means to reduce force generation costs.

- Joint interoperability is an essential requirement and any coordination initiative is welcome if it is sound with the CD&E mandate. For this reason, CFAWC is subject to the guidance of Canadian focal point and repository for information on Modeling and Simulation: the Synthetic Environment Coordination Office (SECO). Furthermore, as the Tier-3 [14] portion of CD&E for the air environment, it is likely to adopt practices from the Canadian Forces Experimentation Centre (CFEC).

- A CD&E organization relies on major projects to build the persistent synthetic environment infrastructure. Therefore, CFAWC strongly relies on the outcomes of the Canadian Advanced Synthetic Environment (CASE) project.

- The efficiency of M&S to achieve valuable outcomes must be demonstrated.

- Operational researchers are well positioned into the CD&E teams to help involving the technical SMEs in the CD&E process.

Since CFAWC has been just newly created, their CD&E process is still in definition. For this reason, DRDC Valcartier will base its analysis on a generic process. The current VAM project focuses on the requirements for interactions with the S&T community, which are applicable whatever their choice of CD&E process.

Moreover, several major M&S projects have been dedicated at demonstrating the relevance of M&S for the conduct of specific scenarios. Very few lessons learned were applicable outside of the scope of the underlying scenario. For this reason, this project was conducted without any specific scenario, technology or concept in mind. It is the time to evaluate the basic requirements that are common to these activities in order to develop a common infrastructure for the conduct of future M&S-based CD&E.

3. Analysis of S&T support to CD&E

The optimal intervention of S&T into CD&E is not straight forward because of the different perspectives of each community. In order to devise the requirements for an appropriate S&T support to the CD&E process, this chapter presents an analysis of the current practices and identifies where S&T can interact within the CD&E process.

3.1 Assessment of current practices

Several challenges arise when trying to isolate the S&T contribution to CD&E. In the CD&E process, the engineering-level knowledge needs to undergo through several procedural and technical layers, from models to simulations, experimentations and analyses. Beyond the challenge to perform the right R&D, the engineering-level S&T SMEs must ensure they produce usable outcomes, while input and output requirements transit through multiple contributors. In this case, roles and responsibilities can become so confused throughout the process that the S&T SMEs' contribution can be inadvertently bypassed. Consequently, this project is looking for solutions to take into account the engineering knowledge in the CD&E process in order to give access to the full range of potential concepts and to ensure their technical validity. Discussions with the clients led to the observation that disconnections between the S&T and the CD&E communities occur at the procedural and technical levels.

3.1.1 Procedural challenges

Procedural challenges refer to the difficulties that arise from the intrinsic ways of doing R&D and CD&E or from the internal processes of the corresponding organizations. The main obstacles that were observed are listed below.

- Each contributor to CD&E has their own roles, responsibilities and mandates that are translated into processes and CONOPS. The collaborations with other organizations are generally stated in a vague manner, leading to overlaps or gaps of roles, responsibilities and mandates.

- The long-term nature of R&D projects implies a slow iteration rate that is not necessarily appropriate to CD&E, where rapid feedback is required to allow for timely convergence despite the fuzzy requirements available at the beginning.

- The interaction with S&T SMEs, as conceived by most CD&E organizations, requires the posting of a few SMEs on the CD&E teams. However, it is hard to attract S&T SMEs for a term that may not be entirely in line with their career advancement [18]. Furthermore, it does not necessarily give access to the full extent of available expertise.

Therefore, different ways of proceeding should be institutionalized. Both operating processes and administrative mechanisms should give flexible access to S&T SMEs, above the regular service-level-agreement, for punctual needs over a long-term continuous support.

Theses challenges will influence the requirements for S&T support to the CD&E process.

3.1.2 Technical challenges

Technical challenges refer to the technology limitations preventing the immediate and natural connection between S&T SMEs and CD&E. The challenges identified within the context of the current study are listed below.

- Little common infrastructure, interfaces, tools and practices to support a persistent collaboration.
- Traditionally, CD&E is associated to operational research and war gaming. The techniques used may require an adaptation to efficiently integrate engineering-level knowledge.
- Engineering-level S&T SMEs' knowledge is generally captured ad hoc, without consideration for reusability benefits such as time and cost saving for designing a new experiment.
- The various CD&E techniques may require different levels of knowledge. The challenge is to determine what level is appropriate in each case. SMEs' role varies from one CD&E activity to another. Therefore, it becomes difficult to standardize a technology since the representation changes with the knowledge level to be delivered.

Theses challenges will influence the technologies chosen to implement S&T support to CD&E.

3.2 Where S&T can interact in the CD&E process?

The analysis of the CD&E processes, shown in Figure 2 and Figure 3, identifies occasions where interaction with S&T occurs.

The first opportunity is at the "call for ideas" step. At this time, the capability to be addressed has been identified and is submitted to the SME for consideration. In response, conceptual ideas are submitted.

Then, the selection of promising concepts and the preparation of the experimentation plan occurs. Some involvement of the S&T SME may be necessary in some cases and it is likely to occur through a committee representative. The concept selection involves the evaluation of the different components of the PRICIE [8], in which S&T SMEs address mainly the “R” (R&D/OR) aspect.

The second significant area of interaction is within the iterative concept experimentation and improvement cycle. During this cycle, the concept proposed is evaluated using an experimentation plan and improvements to the concept are performed at each cycle in order to develop it. The S&T SMEs contribute to evolve the technical achievability of a concept and to verify and validate the concept implementation to be used in experimentations.

These two of interaction are illustrated in Figure 4.

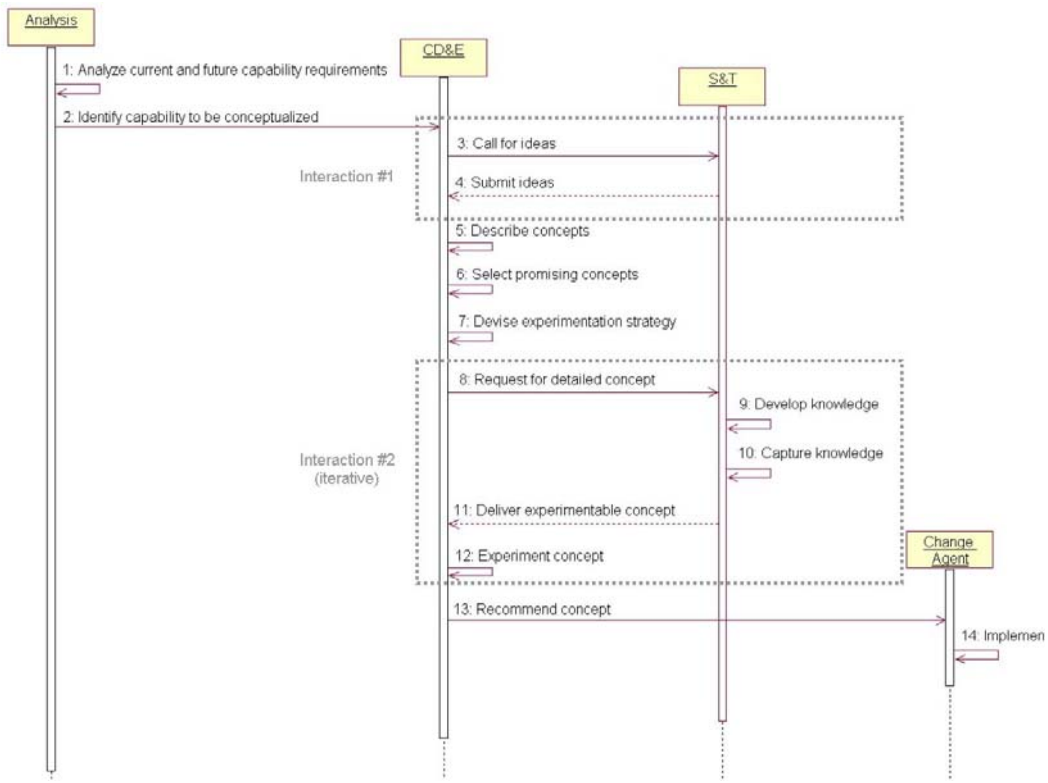

Figure 4. Interactions between CD&E and S&T

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4. Requirements for S&T interactions with CD&E

The analysis of the CD&E process lead to the identification of two main interactions where S&T provides support to CD&E:

- the call for ideas to get concept proposals; and,
- the iterative concept experimentation and improvement cycle.

This chapter presents the requirements needed to ensure an efficient interaction with S&T SMEs for the conduct of CD&E. These requirements do not define how to conduct CD&E but define how the interaction with S&T must be performed when conducting CD&E activities.

4.1 CD&E process requirements for interaction with S&T

The requirements listed below have been identified for any of the two interactions.

- The process for S&T interaction must be embedded into the CD&E process.

  The specification of the interaction between the two organizations during the process ensures that the suitable mechanisms and tools are in place when required.

- The communication channel(s) must be defined in the process.

  This requirement is essential in order to ensure that proper records are maintained and to ensure that tasks or requests can be tracked.

- The process must be based on a technical infrastructure that is versatile enough to permit all levels of interaction.

  This requirement is defined in order to accommodate all levels of interaction related to S&T contribution, whether it is for a parametric data set, a model, a proposal evaluation, an advice, an independent validation, etc.

  Additionally, the interaction must make a compromise between the long iteration time required by the R&D and the required responsiveness of the CD&E community.

- This process must be based on continuous support and long-term proactive collaboration.

Additionally, the interaction plan must include:

- the acceptance requirements (for example, inspired from a VV&A accreditation requirements report [19]);
- the information transfer format;
- the required responsiveness;
- the required iteration cycles;
- the required persistence of the deliverable;
- etc.

The development of this interaction infrastructure requires a significant investment of time and resources, to ensure CD&E applications will be able to support on going CD&E rather than continuously redefining an infrastructure.

In addition to these common requirements, detailed requirements apply to the individual interaction process.

4.2 Requirements for the concept proposition and call for ideas process

The procedure to request concept ideas in order to address identified capability deficiencies is rather complex. The first problem arising is to communicate the problem so that the targeted audience properly understands the scope of the problem. The requirements to properly conduct this part of the process are listed below.

- The targeted audience must be contacted and tasked to propose solutions.

    The process must ensure that proper information reaches the right SME. As stated in the generic requirements for interaction process, a response must be provided in the right format and be timely.

- The process must allow for spontaneous submission of ideas.

    In some cases, concept ideas can be spontaneously proposed by an SME to address a capability that was not formally characterized as deficient, but the proposed concept would be so fantastic that it would create a totally new capability never imagined before. It is thus important to ensure that the infrastructure supporting the exchange of capability is considered and that the concept proposal process is bi-directional.

- The proactive interaction between the two communities shall be initiated at the military requirements level.

- The engineering-level community shall comply with the higher-level perspective of the CD&E community.

4.3 Requirements for the concept experimentation and improvement cycle

As opposed to the call for concept ideas process that occurs in a timely manner, the concept experimentation and improvement cycle is of longer duration. The requirements for that part of the interaction process are listed below.

- The interaction process for concept experimentation must allow for inter-organizational tasking.

- The process must provide access to the required S&T SME for several time-critical events over a long period.

- The necessary steps for mandate creation and financing must be included and must closely follow the pace of the continuous collaboration between the different organizations.

- During this part of the process, the expertise of the S&T expert must be captured and transferred adequately.

- The process must undergo rapid iterations to compensate for new concept requirement unknowns and to ensure timely convergence at the time scale suitable for CD&E needs, as opposed to the slower R&D time-scale.

- The process must accommodate development and experimentation of all types of concepts (military, institutional, operating, functional and enabling concepts [11]).

- Concept experiments must be able to adapt to the appropriate level of detail, fidelity and formalism described as the experimentation requirements space in Figure 5.

Depending on the type and level of maturity of the concept, the interaction process and the concept representation will change. In all cases, the concept representation format must be:

- readily usable for experimentation; and,

- characterized by concept accreditation requirements.

These last requirements impose on the concept developer a rigorous methodology to efficiently develop and capture the required knowledge of the proposed concept.

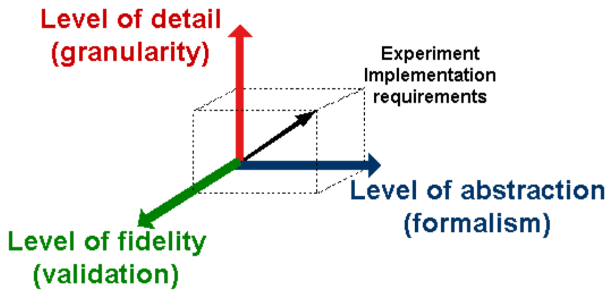

Figure 5. Technological infrastructure for S&T support to CD&E

4.4 Possible state-of-the-art technical solutions

This sub-section presents possible technical solutions to address the requirements for the S&T interaction in the CD&E process. The solutions are of two natures:

- The infrastructure solutions address prerequisite technologies required for the conduct of CD&E activities and to present concepts; and,
- A conceptual technical solution is the methodology by which the S&T SMEs' knowledge relevant to the concept is captured for development and experimentation.

4.4.1 Infrastructure

For the formal "call for ideas" from S&T SMEs, a broad communication method such as a collaborative engineering environment portal [20] is an option. In order to work proactively, the SMEs need to be aware of the preoccupations of the CD&E teams.

The proposed process could be categorized as an Integrated Concept Team (ICT) [21] that has to support the distributed location of the participants and continuous and iterative requests and replies.

In response to the observations made within the Canadian context, the technology to support a continuous proactive collaboration between ICT members requires the features listed below.

- The supporting technology must integrate technical and logistic infrastructures to allow collaborators to interact at an acceptable rate.
- The infrastructure must provide persistent collaboration to ensure responsive interaction with S&T SMEs. The CFAWC Master

Implementation Plan [5] indicates that the scientists would continue to reside in their respective DRDC research centres and assist CFAWC CD&E activities through a technical infrastructure that would support collaboration through geographically distributed sites, depending on the issues and expertise required. This area of defence science support will be further defined as the CFAWC develops. A related initiative is the Capability Transition Group (CTG), which gives feedback on new technologies to the Canadian Forces. However, it is believed that a more proactive innovation would be desirable to efficiently accomplish the Canadian Forces transformation [14]. The S&T support to CD&E should include mechanisms to ensure that DRDC is aligned with the AF future needs that are usually initiated at the CD&E level. This will ensure a higher transfer ratio of R&D products from the S&T community to the AF community.

- The infrastructure must establish collaborative and integrated tools for CD&E, such as M&S that is an enabler to such a collaborative and integration work.

- The infrastructure must be scalable over time to accommodate CD&E projects, but a minimum infrastructure must be established prior to its first use for CD&E.

- The infrastructure must be adaptive and flexible to accommodate the various interaction levels appropriate for each experimentation type and to maximize reuse between experimentation levels.

Figure 6 illustrates the global infrastructure proposed to support the S&T collaborative work for CD&E. A possible implementation of this infrastructure could be a web-based collaborative development tool to support the persistent and iterative interchange process between the participants. The request and reply administrative mechanisms should also transit through a web portal to meet the required timelines. A current Canadian initiative in that direction involves the use of virtual teamwork for collaborative capability development [22].

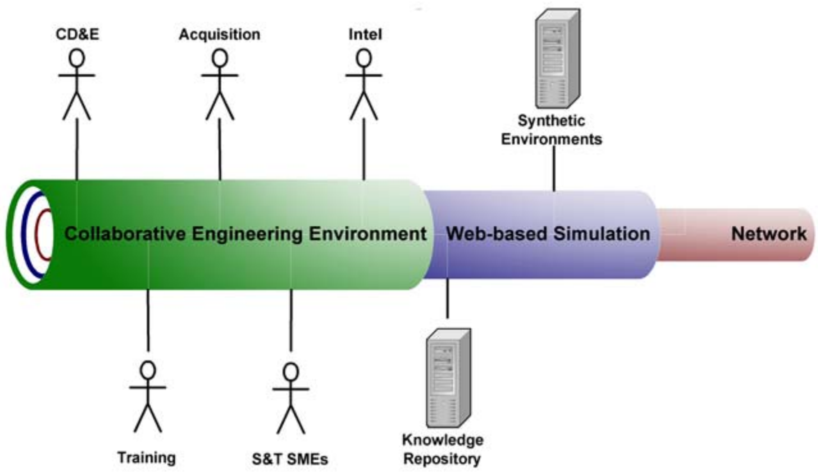

Figure 6. Technological infrastructure for S&T support to CD&E

4.4.2 Concept presentation

M&S is a technology to support the presentation of concepts in a living format allowing people to experiment with them. If the infrastructure selects M&S services, this will support the second interaction between S&T and CD&E.

From a S&T perspective, the technical SMEs must apply a rigorous modelling methodology to efficiently develop and capture the required knowledge in a format compliant with the selected experimentation technique. Such a methodology to capture S&T SMEs' knowledge in a living format and to leverage engineering-level M&S has been demonstrated previously in the KARMA project [23]. In this S&T initiative, an integrated suite of tools guides the whole process from conceptual modelling to synthetic environment component generation. It is an option to comply with the engineering-level practices on one side and to deliver the expertise in usable format for CD&E on the other side. The KARMA methodology and infrastructure implement the Model-Driven Architecture (MDA™) [24, 25, 26]. According to the MDA™, the reusable part of the knowledge can be captured in a conceptual model of the mission space where both technical and operational SMEs agree on a common body of knowledge that is reusable whatever the implementation, scenario or experiment. S&T SMEs benefit from the use of MDA™ to ensure a reasonable return on their M&S investment and to remain responsive to their various clients, since the same knowledge can be required in different formats for different experimentations. However, several issues remain to combine very different models in the same framework (multi-modelling) and to capture very different knowledge and translate it into usable models (multi-formalism modelling). Additional efforts must also be dedicated to the accreditation, the timeliness and the actual usability of S&T deliverables. Future work in preparing technologies to implement S&T support to the CD&E process will have to address these issues.

From the CD&E perspective, the use of a modern simulation technology, such as a persistent and extensible synthetic environment, can significantly reduce the time to set up an experiment. For example, the CASE project [1] and the US Joint Distributed Continuous Experimentation Environment (DCEE) [27] are initiatives where the need for a standing simulation infrastructure has been identified. These technical frameworks would also benefit from being connected to the collaborative environment. One could also envision performing a web-based simulation as proposed by the Extensible Modelling and Simulation Framework (XMSF) initiative [28], which is a step further than the High Level Architecture (HLA) and the Federation Development and Execution Process (FEDEP) in terms of reusability and persistence [29].

This chapter identified the essential requirements for an efficient and productive interaction with the R&D S&T community. The next one adds supplementary information from an independent perspective.

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5. Additional considerations

To ensure that all aspects of the VAM project have been covered thoroughly, external resources have been used to independently validate DRDC Valcartier's perspective and provide a complementary review.

5.1 Independent validation

DRDC Valcartier's perspective has been independently validated by a contractor, namely G&A, [30] and by Operational Research (OR) scientists posted at CFAWC [31]. They have raised the following important considerations that are critical to the success or failure of a formal S&T support to CD&E:

- Cultural Challenge

  It has been brought to the authors' attention that the problem of providing S&T to the CD&E community is a long-standing one. The historical poor cooperation between R&D and CD&E is not only technical and organizational (bureaucratic) but also cultural. This makes the solution to rapid and effective communication even more challenging.

- Distinction Between the Role of R&D and OR Scientists

  Providing an exact definition of R&D, S&T and OR activities is challenging since the spectrum of activities is continuous thus having no discrete boundaries. With this vision, it may appear that there is no gap between the work of R&D and OR scientists. However, the fact that R&D scientists work at expending scientific knowledge while OR scientists focus on using collaboration between the two rather problematic. One aspect that CFAWC OR and G&A people pointed out is that CFAWC CD&E is driven by Operational Research (OR) and OR should seek advice on S&T. Therefore, future work should explore how OR people could seek advice from S&T people. The recent integration of the Centre for Operational Research and Analysis (CORA) to DRDC should facilitate the synergy.

- Relation with CASE

  The CASE project has been identified as an essential enabler for S&T support to CD&E. Although the current focus of CASE is more on Distributed Mission Training (DMT) and Distribution Mission Operation (DMO), the CASE communication and collaboration infrastructures and tools will meet many of the requirements identified during this Project. It is trivial that the technical solutions introduced in Section 0 must optimally leverage the CASE infrastructure and be fully integrated with it. However, since CASE and CFAWC are two structures under definition, it is wise to conduct the current analysis in a generic and unbiased fashion.

- Importance of KARMA

    The external sources questioned why the potential of the KARMA methodology and infrastructure [23] has not been emphasized, although it is key to the solution. Since this analysis was intended to be unbiased and generic, KARMA was noticed as a valuable Canadian initiative and references were given for further information. The idea was to raise the importance of the MDA, which is gaining momentum in the M&S community and which is an enabler to efficient concept presentation. It is a research area that should be investigated and applied in the VAM project follow-on, through KARMA or through any new implementation.

- Verification, Validation and Accreditation

    The current report seems to assume that VV&A is a solved issue. Of course, it is not, but it was not the purpose of this analysis to focus on VV&A. However, it is believed that close input of S&T experts to the CD&E process will certainly help to improve VV&A. With a close relation with S&T, CD&E will benefit from the continuous evolution of VV&A in the S&T community. Conversely, the M&S experts need practical cases to validate their models. Since validation is all about "building the right model", the research in S&T support to CD&E will include finding the "right" model for different types of CD&E campaign. For example, the appropriateness of a model can be defined in terms of requirements for numerical accuracy, domain of validity, robustness and execution time constraints.

- Level of Interaction

    CFAWC and G&A personnel believe that S&T is more likely to be involved in concept triage and prioritization than in iterative concept development. It is more realistic to have an S&T expert participate for a few days in a workshop than develop a concept during a few months. This interaction is performed by the Air Force Research Working Group (AFRWG) of CFAWC's CD&E Process [5].

- Single Point-of-Contact and Unique Business Process

    From a customer perspective, access to S&T expertise is not obvious. Finding the right point of contact to obtain project content approval, financial support and the right scientific resources is not trivial. The need for a single point-of-contact for all DRDC research centres and similarly for each DND customer (e.g. CASE and CFAWC) would minimize the reliance on personal contacts and intermediaries.

In summary, the independent validation emphasized several issues that were not identified in DRDC's preliminary analysis. It also supported DRDC's generic approach to the problem in that it is not tied to any specific CD&E structure or process.

5.2 Independent perspective

In addition to independently reviewing DRDC Valcartier's proposal, G&A also produced an independent analysis [8] of the problem from a different and complementary perspective.

G&A presented a larger overview on CD&E in general, including the 3-Tier approach to integrated CD&E that has political and organizational influence at joint, strategic and operation levels and at the tactical air, maritime and land levels.

While DRDC's technical report describes CD&E from a technical evaluation and practical implementation stand point (processes and technologies), G&A reviewed the subject from a conceptual and organizational perspective, such as concept hierarchy and PRICIE components.

G&A emphasized the S&T support process with respect to other political initiatives such as the Canadian Joint Task List (CJTL) and the capability-based planning. They stated that S&T programs should adapt to strategic needs, through the Structured Analysis of Issues and Lessons (SAIL) Directorate for example, in order to timely align ongoing R&D work to upcoming CD&E campaigns. Capability roadmaps, as addressed by the CapDEM technology demonstration project [6], will help to achieve such responsivity.

According to G&A, CapDEM has an important role in supporting S&T involvement in CD&E. Although CapDEM originally focused on the acquisition part of the life cycle for defining component systems and functions, the principles could be applied in a pre-CD&E phase. CapDEM does not aim at defining how to do CD&E, but help to define a way to process the capability gaps. From the Capability Engineering Process (CEP), an integrated architecture to capture the requirements, such as the US Department of Defense Architecture Framework (DoDAF), could be applicable to the development of CD&E campaign plans.

G&A's report also mentioned that most M&S activities performed in CD&E focus on experimentation. A concept is experimented using M&S in order to obtain a measure of effectiveness. There are no reported examples of the application of M&S in the concept development process. G&A suggests that the overall objective should be to establish an integrated M&S backbone for the entire CD&E process.

Since these complementary subjects are already well explained in G&A's report [8], they have purposely not been detailed in the current chapter. The new issues raised in this chapter are considered in the final recommendations.

6. Convergence and recommendations

The initial scope of the VAM project definition phase was to define the process and the technology required to provide S&T support to air warfare CD&E. However, the definition phase revealed that air warfare CD&E is far from having reached the level of maturation needed to adopt a definitive formal process and technologies for S&T support to CD&E. It is thus envisioned that the required technologies would be implemented during follow-on research projects. Therefore, the definition phase resulted in defining a work plan to develop the building blocks for S&T's complete and formal support to CD&E. This will ensure that the chosen approach is appropriate and adapted to the evolving CFAWC.

The deficiencies identified during the VAM definition phase include the need for education, methodologies, tools, collaboration, validation, repeatability and measurability. In brief, the challenge can be summarized as a need to improve the level of maturity of the CD&E process. This chapter introduces the concept of a CD&E maturity model. Then, high-level actions are suggested to enable collaborations prerequisite to upcoming S&T support. Finally, a plan is proposed for the specific S&T contributions in the form of a formal research strategic plan.

6.1 CD&E maturity model

For more transparency, the CD&E process needs to evolve from an ad-hoc process to a structured process and this cannot happen instantaneously and persist without effort. It is a continuous evolution, similar to team software development, system engineering, etc. An analogy can be done with the Capability Maturity Model Integration (CMMI) [32]. This model characterizes, among others, the level of maturity of the software development practices in a development team. It suggests best practices for high-quality development, self-evaluation and self-improvement. Table 1 presents in a generic fashion the 5 levels of the CMMI.

These ideas could be mapped to the CD&E world and specific best practices could be developed. The fact that CD&E processes already exist is an excellent starting point that could correspond to the "managed" maturity level. Standardizing tools and methods such as the systematic usage of M&S could improve the cost effectiveness and the responsiveness and make it "defined". Adding VV&A and metrics to M&S could make it "quantitatively managed". Reuse, interoperability and configuration management could make it "optimized".

The VAM project definition phase does not intend to state a complete maturity model for CD&E, but the follow-on projects should contribute to define one or simply start proposing and implementing best practices. Even if DRDC resources are not used to assist with process management, the importance of a CD&E maturity model should not be neglected since the main deficiencies identified in this project are related to organizational and procedural issues.

Table 1. CMMI Summary

MATURITY LEVEL	DESCRIPTION
Level 1 “Initial”	Processes are usually ad hoc and chaotic. The organization usually does not provide a stable environment. Success in these organizations depends on the competence and heroics of the people in the organization and not on the use of proven processes. Products and services often work, but they frequently exceed the budget and schedule. These organizations have a tendency to over commit, abandon processes in the time of crisis, and not be able to repeat their past successes.
Level 2 “Managed”	The projects of the organization have ensured that requirements are managed and that processes are planned, performed, measured, and controlled. The projects are performed and managed according to their documented plans. The process discipline ensures that practices are retained during times of stress.
Level 3 “Defined”	The processes are well characterized and understood, and are described in standards, procedures, tools, and methods. The organization’s set of standard processes is established and improved over time. These standard processes are used to establish consistency across the organization. Projects establish their defined processes by tailoring the organization’s set of standard processes according to tailoring guidelines.
Level 4 “Quantitatively Managed”	Sub-processes are controlled using statistical and other quantitative techniques. Quantitative objectives for quality and process performance are established and used as criteria in managing predictable processes. Quantitative objectives are based on the needs of the customer, end users, organization, and process implementers. Quality and process performance are understood in statistical terms and are managed throughout the life of the processes. Quality and process performance measures are incorporated into the organization’s measurement repository to support fact-based decision making in the future.
Level 5 “Optimizing”	The processes are continually improved based on a quantitative understanding of the common causes of variation inherent in processes. This level focuses on continually improving process performance through both incremental and innovative technological improvements. Process improvements to address common causes of process variation and measurably improve the organization’s processes are identified, evaluated, and deployed. Improvements are selected on the basis of a quantitative understanding of their expected contribution to achieving the organization’s process-improvement objectives versus the cost and impact to the organization. The organization’s ability to rapidly respond to changes and opportunities is enhanced by finding ways to accelerate and share learning. Improvement of the processes is inherently part of everybody’s role, resulting in a cycle of continual improvement.

6.2 Collaboration-enabling actions

Several collaboration-enabling actions can be taken to leverage the combined expertise of CFAWC and DRDC. The challenges identified in the analysis of current practices (Section 3.1) need to be settled by a collaborative effort of both DRDC and CFWAC.

For DRDC, the actions below are recommended.

- Align S&T thrust activities to CD&E campaigns.

    At the management level, DRDC should endorse scientists’ participation in CFAWC activity. One method is to partially align

S&T thrusts, i.e. the choice of technologies being explored, to the subjects of the CD&E campaigns. Another method is to improve the scientists' awareness or understanding of the content of the ACF in order to self-synchronize with the operational community. These actions will maximize the likelihood of technology transfer to the Canadian Forces.

The principal challenge is to provide a timely response to the needs of specific CD&E campaigns. The management should ensure that the research projects contain an option for direct support to CD&E campaigns with the rapid delivery of CD&E-usable data. The data may include only partial and preliminary research results, but at least it will be timely for some needs.

In addition to the CD&E campaigns outcome focus, R&D investment in enabling tools and technologies either based on modeling and simulation technologies or in metrics, validation and analysis methods could initiate long-term collaborations. This issue is the specific subject of the VAM project definition phase and will be detailed in a formal plan in Section 6.3.

- Self-market.

  DRDC should continue to market its capabilities. The absence of specific technical content on DRDC web site and Defence Information Network (DIN) site does not convince the reader that valuable resources are available. DRDC should market itself from a technical point of view using specific projects and outcomes and not only from a corporate image with generic fields of expertise.

- Redefine the synergy between OR and R&D scientists.

  DRDC has to improve its reward policy to foster an OR change of mind toward lasting development and R&D scientists change of mind toward close involvement in operational projects. This issue should be addressed during the current redefinition of the linkage between CORA and DRDC. In practice, it could include the assignment of OR positions in DRDC's Service Level Agreement (SLA) projects.

For CFAWC, the actions below are recommended.

- Change the CFAWC CONOPS to include active participation of S&T SMEs.

  Given that DRDC takes the necessary actions to endorse and provide the required participation, S&T SMEs should systematically interact in the CD&E process, beyond the regular posting of scientists and their participation in committees.

- Fund enabling technologies.

  In parallel to its Business Line 1 (BL1) research program, DRDC can accept extra mandates to specifically answer short-term needs of the Canadian Forces. CFAWC could benefit from the tailored expertise of DRDC's scientists instead of redeveloping the required knowledge.

- Educate on collaboration, M&S and best practices.

  CFAWC has the advantage of being a new organization not too tied to the old "quick hit" CD&E philosophy. However, it is critical to educate each new team member on the role of M&S as an enabling technology providing resources and tools to achieve the desired objectives in a cost and time effective manner. To meet these benefits, education should also include the importance S&T input for model sharing and reuse and best practices for lasting development.

- Manage M&S operation and maintenance.

  S&T can help to improve processes and tools through M&S-based CD&E. However, to really increase its level of maturity, CFAWC will have to manage these new technologies. CFAWC should prepare for this transition in establishing a strong M&S management plan, including infrastructure, process and resource management. Close collaboration with SECO is advised.

- Define and deploy CASE for CD&E.

  As an Air Force organization, CFAWC should play an active role in the definition of CASE, its contribution to air warfare CD&E and its progressive deployment at CFAWC. This action could take the form of a participation in a CASE exercise, for learning and infrastructure deployment purposes. It could also occur through the attendance in CASE working groups.

6.3 Proposed strategic plan for DRDC support to CFAWC

From these requirements, DRDC Valcartier extrapolated a project roadmap that intends to serve as a strategic plan for the DRDC Thrust 3j "Air Mission Systems" support to CFAWC. The objective is to organize the support to CFAWC, to maximize the synergy between the projects and to build upon the results of each project to develop a final and common process and technological infrastructure that will gradually improve the maturity of the air warfare CD&E. The following paragraphs briefly describe the logical steps to identify the potential projects.

6.3.1 Capability gap / critical future goal

The critical future goal is to conduct CD&E as an enabler for robust, affordable, timely and interoperable Air Force transformation in a joint context.

6.3.2 S&T outcome

To achieve the capability above, S&T should assist CFAWC in the definition and development of its processes and infrastructure.

6.3.3 S&T gaps / deficiencies

In order to deliver the S&T outcome, the following S&T deficiencies and gaps should be addressed:

- ability to request, access, use and deliver S&T expertise in the CD&E process;
- ability to deliver S&T timely outputs;
- ability to propose interoperable S&T solutions;
- ability to demonstrate the value of M&S to reduce force generation costs; and
- ability to cooperate with OR scientists.

6.3.4 R&D objectives

To solve these S&T deficiencies, four R&D objectives have been identified:

- define and configure M&S resources to support CD&E;
- develop methods and tools to capture, filter, develop and evaluate concepts;
- acquire specific expertise to select relevant concepts and to design and conduct experiments to evaluate concepts; and
- create project teams composed of R&D and OR scientists.

6.3.5 R&D projects

In order to fulfill the R&D objectives, a series of projects have been developed. They will support to the development of the CD&E process, CD&E infrastructure and specific CD&E campaigns. The first two categories directly contribute to the improvement of CD&E maturity although the ongoing applications are essential to achieve it in practice. All projects will contribute to the conceptualization and implementation of the Virtual Air Mission Space.

Furthermore, these projects are not intended to be conducted by DRDC Valcartier. Every DRDC research centre, section or group can have a contribution at one level or another. However, for process and infrastructure development, most of the tasks would probably be assigned to DRDC Valcartier, DRDC Ottawa (Future Forces Synthetic Environment Section), Director Research & Development Knowledge and Information Management (DRDKIM) or CORA. CFAWC may also need to conduct some tasks.

6.3.5.1 S&T support to the development of the CD&E process

DRDC can help to modify the CD&E process to take into account capability gaps and to better deliver capability requirements, the aim being to improve relevance, robustness and to reduce the time and cost. DRDC can also help to efficiently take advantage of S&T resources along the CD&E process through the projects listed below.

- M&S for CD&E.

  To provide CD&E with a persistent infrastructure, the location of M&S and a synthetic environment need to be defined. This project would evaluate and expand the role of M&S in concept development. It could also investigate how to plan an M&S-based experiment, how to conduct it and how to draw conclusions from it. It could include the documentation of an experiment, the development and the analysis methodology. Furthermore, M&S-based measures of effectiveness and measures of performance of a concept could logically be derived.

- Capability engineering applied to CD&E.

  As stated in Section 5.2, the CapDEM technical demonstration project has developed a rigorous process to engineer capabilities for acquisition purposes through simulation-based acquisition. This project would investigate how the CEP could serve the needs of CD&E, for example in defining the capability gaps, the concept development and the experimentation plan requirements.

- Advised concept development.

  This project could investigate and experiment different methods to access and transition S&T expertise to get, sort and iteratively develop concepts. For example, figures of merit could be developed to measure the effectiveness of different approaches such as portal forums, workshops, committees, models, result data, report, etc.

- Physics-based M&S support to CD&E.

  It is generally accepted that M&S can improve the robustness, timeliness and cost-effectiveness of CD&E. However, little is known regarding the appropriate M&S for CD&E. This project would demonstrate the value of M&S to conduct CD&E and deliver a capability. It would address VV&A and metrics to determine the appropriate level of detail of M&S for CD&E. It could also include the experimentation of methodologies and modelling infrastructure to transition S&T expertise through M&S.

6.3.5.2 S&T support to the development of the CD&E infrastructure

A mature CD&E process needs to reside on a solid, efficient and persistent infrastructure to dedicate the efforts on the campaign itself.

The use of a synthetic environment seems to be the logical choice to meet the transformation requirements, but the CD&E community has not yet identified the components and tools that would meet the expectations. M&S and SE expertise exist in DRDC's research laboratories to support CFAWC in the implementation of its CD&E infrastructure. The projects listed below cover all the components deemed essential to a complete infrastructure.

- Simulation environment for CD&E.

  One of the objectives of S&T is to improve the technological means to conduct CD&E. Therefore, the simulation environment should be seen as another tool, amongst all other CD&E techniques to achieve concept development, experimentation and evaluation. This project would investigate, develop and experiment different simulation environment configurations to determine the optical infrastructure that meets the requirements for collaboration, distribution, persistence, infrastructure to support a broad range of CD&E campaigns.

- Evaluation tools for CD&E.

  CD&E can certainly leverage simulation environments from other domains, such as training or acquisition. However, the analysis of simulation results may need to be specifically tailored to concepts evaluation. This project could investigate, develop and experiment how analysis tools can be tailored to CD&E while being persistent to be applicable across a broad range of simulation tools and CD&E campaigns.

- Self-maintaining searchable expertise directory.

  This directory could be used to invite the appropriate S&T SMEs to the AFRWG meetings, to rapidly order models to the right people or to establish a campaign-specific project. Although this project would be under the responsibility of an organization such as DRDKIM, it is a research project in itself. Indeed, current knowledge management tools do not allow achieving the level of interaction and persistence needed for a long-term collaboration with CFAWC. Such a project could investigate, develop, experiment and deploy a self-maintaining searchable expertise directory. It could be based on mind mapping tools to capture the expertise of each scientist with DRDC-wide parsers to collect and integrate the expertise and browsers to represent the information according to the different clients requirements. Air warfare CD&E could be the first test bed for this expertise directory, although several other benefits should arise from the project, such as better internal knowledge retention and dissemination.

- Collaborative development and experimentation network.

  Most CD&E campaigns will deal with complex problems that need to be addressed by a multidisciplinary team. Today's technologies allow changing the traditional approach where team members had to meet together. Now, exchanges, development, conferencing and experimentation can occur in a distributed fashion through a network. Therefore, this project could investigate, develop and experiment network configurations adapted to the S&T and CD&E collaboration, to multi-level security experimentation, to persistent connection, to agile reconfiguration, to M&S performance, etc. This project could easily leverage on the CASE experience.

- Collaborative development and experimentation portal.

  A network infrastructure is a prerequisite to collaborative work. However, a project on a collaborative development and experimentation portal would improve the usability of the network technology. This project would investigate how an Internet portal could contribute to the transparency of the CD&E process during concept capture, prioritization and triage. It could also be extended to link with an expertise directory, the network configuration, the software development of the experimentation, the experimentation itself and the evaluation of concepts. In brief, the portal could become the main thread of the whole CD&E process and the collaboration around it.

- Resource repository for CD&E.

  All the other component of the infrastructure contribute to conduct CD&E campaign. Although designed to be applicable throughout several applications, they do not manage the persistence of the knowledge. A project should investigate, develop, experiment and populate a CD&E resource repository to serve as the configuration management tool for up-to-date and reliable information. The project would have to address how to insert its usage in the CD&E process to pick-up and dump the information. The resource repository will have to link with all of the other infrastructure components to easily instantiate information, such as a model in a simulation framework. Gradually, the repository would be populated with a proper set of models of Canadian equipment and threats to be reused from one campaign to another. Within this context, the project could also study reuse applicability, assets documentation (level of detail, validation, performance, interface, etc.) and maintenance. The resource repository could become the instrument for expertise transition between DRDC and CFAWC.

6.3.5.3 S&T support to specific CD&E campaigns

Finally, S&T projects could be created to support specific CD&E campaigns. In such projects, the tasks could include the participation in S&T gap identification, concept elicitation, triage and development, experimentation development and concept evaluation. In particular, the scientists could provide technology monitoring, literature review, system expertise, models, data, validation, etc. The S&T support to CD&E process and architecture development would help to specify the support expected during specific campaigns.

6.3.6 General advice

Since the objective of the recommendations in this report are to gradually improve the maturity of the air warfare CD&E process, some projects for S&T support to specific CD&E campaigns can occur before the process and infrastructure are completely defined. Both DRDC and CFAWC must be prepared to work in a spiral approach. This is the solution to a persistent and maturing capability.

The projects should use realistic pilot CD&E campaigns conducted in parallel with the operational critical path. The focus should be on the process and infrastructure development rather than on the difficulty of the CD&E subject itself.

All of these projects should be seen as CD&E on how to do CD&E, which means that different concepts of S&T support to CD&E can be experimented. An example would be different expertise exchange formats.

Each pilot project should emphasize one primary deficiency, although it is likely to address secondary deficiencies concurrently since all of them are closely related and form a global solution to the problem.

To ensure an optimal synergy and a maximal transfer ratio to the CF, these projects should be conducted in close collaboration with CFAWC. CFAWC personnel should be assigned to CD&E tasks, while DRDC personnel should research and develop what is needed to support them.

Coordination between individual projects, ideally through a Thrust Leader, is also essential to ensure an optimal integration of the results in a global solution addressing all the aspects of S&T support to Air Force CD&E.

In summary, this proposal defines the role, contribution and plan of S&T in supporting Air Force CD&E relative to the mandate of CD&E personnel.

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7. Conclusion

In summary, this report discussed the rationale for formal S&T support to CD&E. CD&E being an enabler for Canadian Forces transformation, it is logical to apply the same capability-driven philosophy to R&D activities. Tailoring R&D for CD&E can optimize the synergy between CD&E and S&T organizations. However, current gaps in procedures and technologies must be overcome to carry out that vision. The process of implementing S&T support to CD&E must break the barrier between organizations. The requirements for such a process have been identified in a generic manner, independently of the technological solutions and specific scenarios. Possible supporting technologies have been presented with the objective of giving an idea of a concrete implementation of the abstract process. The end-customer and a contractor validated DRDC Valcartier's analysis. New issues were raised by the contractor and the end-customer. Finally, DRDC Valcartier provided an integrated proposal for future S&T support to air warfare CD&E.

The envisaged outputs of the Project definition phase were a report describing a process and technologies for S&T to assist CFAWC in air warfare CD&E and also a follow-on ARP proposal to provide components of this CD&E support. Due to the fact that CFAWC was in definition, the Project focused more on identifying process requirements than describing detailed steps. Similarly, since the Air Force M&S infrastructure is also under definition in the CASE project, it was difficult to select supporting technologies. Therefore, the recommendations of the report were adapted accordingly to allow for S&T support to CD&E to develop along the evolution of CFAWC process and activities.

A follow-on ARP project was also proposed to address physics-based M&S support to CD&E. Other funded research projects at DRDC Ottawa will contribute to the improvement of the simulation environment and network. More ARP projects are expected to be funded in the future.

In light of this analysis, it is believed that a coherent S&T strategic plan will improve CD&E maturity through the development of a seamless process and a persistent infrastructure usable across different CD&E campaigns. S&T will contribute to improve the CD&E process, through methodologies and metrics, supporting infrastructure, simulation frameworks for experimentation-specific usage, resource repositories, collaborative portals and network connectivity. Hopefully, the rigorous methodology followed to set up this infrastructure will also lead to an integrated M&S management plan and education program. Finally, if conducted as advised, the greatest benefit of this collaborative development of S&T support to Air Force CD&E should be a consolidated team of CD&E, OR and S&T personnel working together to efficiently achieve robust, affordable, timely and interoperable CD&E campaigns in preparation for future Air Force transformation initiatives.

Beyond CD&E, a coherent strategic plan will also benefit the whole range of virtual life cycle activities. By complying with coordination, commonality and interoperability guidance, the S&T deliverables could become building blocks for the global Air Force synthetic environment.

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List of acronyms

ADM(Mat)	Assistant Deputy Minister (Material)
AF	Air Force
AFEC	Air Force Experimentation Centre
AFRWG	Air Force Research Working Group
ARP	Applied Research Project
CapDEM	Collaborative Capability Definition, Engineering and Management
CASE	Canadian Advanced Synthetic Environment
CD&E	Concept Development and Experimentation
CEP	Capability Engineering Process
CFAWC	Canadian Forces Aerospace Warfare Centre
CFEC	Canadian Forces Experimentation Centre
CGAFC	Centre de guerre aérospatiale des Forces canadiennes
CJTL	Canadian Joint Task List
CMMI	Capability Maturity Model Integration
CONOPS	Concept of Operations
CTG	Capability Transition Group
CORA	Centre for Operational Research and Analysis
D Air SP	Directorate of Air Strategic Plans
DAR	Directorate of Aerospace Requirements
DCEE	Distributed Continuous Experimentation Environment
DIN	Defence Information Network
DND	Department of National Defence
DoDAF	Department of Defense Architecture Framework

DRDC	Defence Research and Development Canada
DRDKIM	Director Research & Development Knowledge and Information Management
DSTA	Director Science and Technology Air
ECC	Évaluation et expérimentation de concepts
FEDEP	Federation Development and Execution Process
HLA	High Level Architecture
ICT	Integrated Concept Team
JSMARTS	Joint Simulation and Modelling for Acquisition, Rehearsal, Training and Support
M&S	Modelling and Simulation
MDA	Model Driven Architecture
OR	Operational Research
R&D	Research and Development
S&T	Science and Technology
SE	Synthetic Environment
SECO	Synthetic Environment Coordination Office
SLA	Service Level Agreement
SME	Subject Matter Expert
XMSF	Extensible Modeling and Simulation Framework
VAM	Virtual Air Mission
VV&A	Verification, Validation and Accreditation

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Modelling and simulation (M&S)

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Process

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