



Defence Research and
Development Canada

Recherche et développement
pour la défense Canada



CapDEM - Toward a capability engineering process

A discussion paper

*F. Bernier
M. Couture
G. Dussault
C. Lalancette
F. Lemieux
M. Lizotte
M. Mokhtari
DRDC Valcartier*

*S. Lam
DRDC Ottawa*

Defence R&D Canada – Valcartier

Technical Report

DRDC Valcartier TR 2004-230

September 2005

Canada

CapDEM - Toward a capability engineering process

A discussion paper

F. Bernier
M. Couture
G. Dussault
C. Lalancette
F. Lemieux
M. Lizotte
M. Mokhtari
DRDC Valcartier

S. Lam
DRDC Ottawa

Defence R&D Canada – Valcartier

Technical Report
DRDC Valcartier TR 2004-230
September 2005

Author

Michel Lizotte

Approved by

Guy Turcotte
Head System of Systems

Approved for release by

Gilles Bérubé
Chief Scientist

© Her Majesty the Queen as represented by the Minister of National Defence, 2005

© Sa majesté la reine, représentée par le ministre de la Défense nationale, 2005

Abstract

The Department of National Defence is implementing Capability-Based Planning as a core element in the overall business process. In this context, the Collaborative Capability Definition, Engineering, and Management (CapDEM) Technology Demonstration Project examines the Collaborative Engineering concept to create a systematic link between the conceptualization of a capability and the detailed definition, engineering and management of the component systems. The current report summarises the initial work conducted, from April 2003 to December 2003, by the CapDEM team responsible to work out the Capability Engineering Process (CEP). It describes the main findings about scoping and applying the future Canadian CEP.

Résumé

Le ministère de la Défense nationale met en place la planification axée sur les capacités en tant qu'élément central de son processus global d'affaires. Dans ce contexte, le projet de démonstration technologique de définition, d'ingénierie et de gestion collaboratives des capacités (DIGCap) examine le concept d'ingénierie collaborative afin de créer un lien systématique entre la conceptualisation d'une capacité et la définition détaillée, l'ingénierie et la gestion des systèmes qui la composent. Ce rapport résume le travail initial effectué d'avril à décembre 2003 par l'équipe de DIGCap responsable de définir le processus d'ingénierie des capacités (PIC). Il décrit les principaux résultats sur la portée et l'application du futur PIC canadien.

This page intentionally left blank.

Executive summary

Background

The Department of National Defence (DND) is implementing Capability-Based Planning (CBP) as a core element in the overall business process. Currently, the CBP process leads to the acquisition of systems within that capability. The aim of the Capability Engineering (CE) concept under investigation in the Collaborative Capability Definition, Engineering, and Management (CapDEM) Technology Demonstration Project (TDP), is to create a systematic link between the conceptualization of a capability and the detailed definition, engineering and management of the component systems. The main outcome of CE is an improvement of decision-making for strategic investment. An analytical process or environment needs to be developed enabling trade-off analysis across systems to evaluate their overall impact on each other or on the overall capability. This process, referred to as the Capability Engineering Process (CEP), must provide rigour and structure to enhance synchronization of capability transitioning.

Figure 1 illustrates these relationships, at the conceptual level, whereby the top of the figure indicates the current process of “leaping” from capability concept to individual component system acquisition, and the bottom of the figure proposes the introduction of CE to provide rigour and structure to that process so as to enhance capability synchronization transitioning.

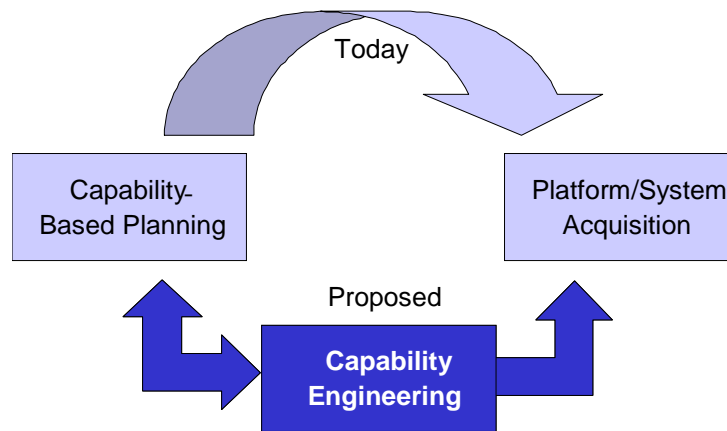


Figure 1: CE in the CBP Process

The application of CE requires a process, supporting tools, and personnel with the skill sets to employ this process and tools. The best source for processes and tools at this time is the System Engineering (SysEng) domain, whereby the community has standardized processes and are actively using and enhancing tools in the area of requirements management, functional modelling, architecture modelling, use case definition, Computer Aided Design and Drafting (CADD), human form and behaviour modelling, life cycle cost modelling, and both constructive and virtual simulation. CapDEM’s hypothesis is that these processes and tools, which are normally applied on a system level, can be extended to the capability (System-of-Systems - SoS) level to

provide the basis for CE. As a result, the baseline definition of CE at the start of this TD is:

“Capability Engineering is the application of system level engineering and management processes and tools to Capability Management in order to establish the necessary rigour for effective planning, acquisition and evolution of a system-of-systems capability”¹

The CapDEM TDP has been established to define CE and to validate the discipline in the Canadian defence context, in collaboration with a wide range of DND and industrial community stakeholders. Figure 2 outlines the project work plan.

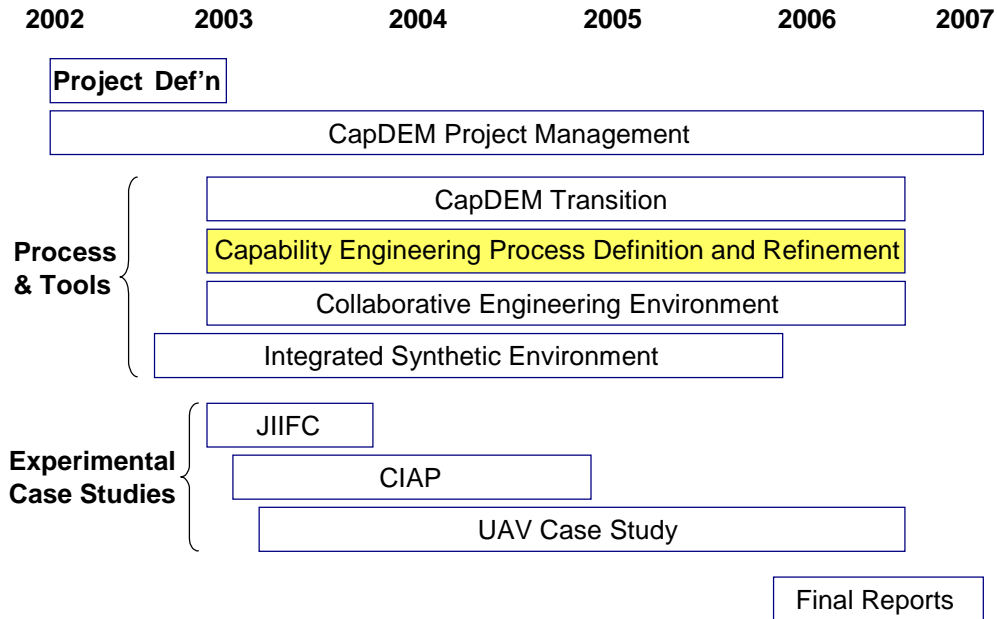


Figure 2: CapDEM Work Streams

Main findings

The current report summarises the work conducted by the CEP Team from April 2003 to December 2003. The objective of this team, for the whole CapDEM project, is to deliver a CEP that meets DND/CF’s needs. The development and evaluation of the CEP will be performed in three one-year cycles during the course of the project.

The specific objective for the first year (ending in March 2004) was to verify if the CEP and Collaborative Engineering Environment (CEE) of the US Office of the Chief ENGINEER (CHENG) under the Assistant Secretary of the Navy for Research, Development, and Acquisition – also called ASN (RDA) CHENG - are a suitable starting point for the project. The CEP Team used a document, provided by Mr. Schmidt through an international team (TTCP JSA TP4²) as the CEP V0 to be used for

¹ CapDEM Management Team, *Project Implementation Plan - Collaborative Capability Definition, Engineering and Management (CapDEM) Technical Demonstration Project*, 5 May 2003, 49 pp.

² TTCP JSA TP4 stands for “The Technology Cooperation Program – Joint System and Analysis Group - Technical Panel 4 (Systems Engineering for Defence Modernization)”

case studies in the first cycle. The specific objective for this first cycle was to deliver an integrated assessment report on the TP4 CEP Working Draft and the tools supporting it.

From the internal literature review on subjects relevant to CE and, analysis of the TP4 CEP Working Draft, the following conclusions were drawn:

- As of December 2003, the Canadian problem was not sufficiently mastered by the CEP Team to recommend or propose a CEP V1. The initial CapDEM view and the TP4 CEP Working Draft provide good definitions of “process” and “CE” but further investigation is required.
- In its current overview version, the TP4 CEP Working Drafts not applicable by itself since there is insufficient documentation available. Many elements, steps and outputs are not clear enough to be useable. The user has room for a lot of interpretation, which could lead to different implementations for the same kind of problem. Considering the limitations of the available information, it is not possible to determine whether the resulting Transformation Roadmap would provide all adequate information to support strategic investment decisions for DND/CF capability implementation.

In addition, during this first part of Cycle 1, the CEP Team has identified:

- Possible scope of the CE such as: aiming at evolving medium-size family-of-systems-based capability in a few months for a specific mission; or aiming at creation, over a long period of time (5 years), a dedicated SoS.
- Possible forms of the process enabling the CE concept examined from different aspects such as: methodology (Spiral, Iterative, Incremental, Waterfall, Custom,...), level of refinement (analysis of alternatives vs Pugh Matrix, 1 vs 20 deliverables,...), completeness (What, When, Who, With What (tools), entrance criteria, exit criteria, goal and reference(s) for each activity, input & output,...); level of adaptability to the organization (activities or deliverables, generic or tailored to an organization...).
- Some candidate solutions have already been applied to solve similar problems e.g. military acquisition (Evolutionary Acquisition, US DoD 5000 documents, CJCSI³ 3170...), software engineering (RUP⁴, UML⁵...), SysEng (IEEE 1220, ISO/IEC⁶ 12207, Spiral Development...), architecture description (DoD AF, TOGAF⁷, Zachmann, Enterprise Architecture...).
- Some elements to be considered for CEP V1:
 - Be adaptable i.e. specify deliverables independent of the utilization context or tailored to the (Canadian) organization;
 - Start from standard approaches and well-known references such as SysEng, software development and, enterprise architecture;

³ Chairman of the Joint Chiefs of Staff Instructions

⁴ Rational Unified Process

⁵ Unified Modeling Language

⁶ Internal Organization for Standardization/International Electrotechnical Commission

⁷ The Open Group's Architecture Framework

- Include an effective usage of Modeling and Simulation in particular, to facilitate the reuse of data supporting it;
- Describe process activities with a sufficient level of detail; and
- Limit the room for interpretation i.e. be self-explanatory and self-contained (comprehensive).

Developing a CEP: Main questions to be answered

During our literature review many questions were raised, many of which address the issues expressed above. Here are the main ones:

- Should CE be able to construct virtual (short-term time frame) and dedicated (long-term time frame) capabilities?
- Should CEP be concerned with self-evolution, joint evolution and emergent evolution (or any other types of evolution) of a capability?
- Is CEP more related to solving these managerial issues of concurrent engineering instead of traditional (but complex) SysEng issues?
- During which phases of the life cycle is CE applied?
- What are the inputs and the outputs of CEP and who will use this information?
- Should CEP be generic or tailored to its context of use?
- Should CEP consider and propose a solution composed of capability subelements (such as DOTMLPF⁸ or PRICIE⁹) or be more selective like the 5000 acquisition strategies?
- Since a capability can be defined at various business and technical levels of granularity, which levels are optimal to reach the objectives of CEP?

These questions are not easy to answer at this moment. A good knowledge of requirements and “as-is” architectures is essential to provide a sound process. It will contribute to the identification of technologies that will form the CEP. It is even possible that the CEP itself will have a different path from one project to another e.g. activities and notation may differ depending on the problem being solved.

It is probable that the solution will be more “dedicated” to one (or a few) project(s). It may be difficult to develop a generic CEP that will address all capability needs in the future. The identification and the understanding of technologies that may form the CEP is an important step in every project. It is also highly probable that new expertise will have to be gathered by systems engineers in order to completely understand and address all inherent aspects of a proposed CEP.

Way Ahead

Many questions remain to be answered before working out the CEP. Many of them will be answered when specific requirements of the Canadian capability development

⁸ DoD acronym for Doctrine, Organizations, Training, Materiel, Leadership, Personnel and Facilities,

⁹ DND acronym for Personnel, R&D/Ops Research, Infrastructure & Organization, Concepts, Doctrine & Collective Training, IT Infrastructure, Equipment, Supplies and Services

community and actual acquisition problems will be identified. Others will be answered by the CEP Team based on its own experience and consultant resources and finally, some will fall within the competence of stakeholders to facilitate institutionalization and resources prioritization reasons. Since the problem space of the CE is very large, an initial solution should tackle only a portion of the problem.

Based on the knowledge acquired during this first nine months, the next priority for the CEP Team is to get a very good understanding of the current deficiencies of the Canadian process. As a first step, the Canadian current situation, “as-is”, will be studied, regarding mainly the current DND project approvals process. In addition, other DND initiatives related to the CEP will be examined. In parallel, a kind of International current situation will be worked out, looking at what is being done outside Canada. From these two “current situations” and lessons learned from two CapDEM case studies, Joint Intelligence and Information Fusion Capability (JIIFC) and Intelligence Surveillance and Reconnaissance (ISR) Maritime the “to-be”, CEP Version 1, will be elaborated and tested using subsets of these case studies.

Bernier, F., Couture, M., Dussault, G., Lalancette, C., Lam, S., Lemieux, F., Lizotte, M., Mokhtari, M. 2005. CapDEM – Toward capability engineering process definition: A discussion paper: A discussion paper. DRDC Valcartier TR 2004-230. Defence R&D Canada.

Sommaire

Contexte

Le ministère de la Défense nationale (MDN) met en place la planification axée sur les capacités (PAC) en tant qu'élément central de son processus global d'affaires. Actuellement, le processus associé au PAC mène à l'acquisition de systèmes impliqués dans la mise en œuvre d'une capacité. Le but du concept d'ingénierie des capacités (IC) à l'étude dans le projet de démonstration technologique (DT) intitulé Définition, ingénierie et gestion collaboratives des capacités (DIGCap) est de créer un lien systématique entre la conceptualisation d'une capacité et la définition détaillée, l'ingénierie et la gestion des systèmes qui la soutiennent. Le principal résultat du IC est une amélioration de la prise de décision pour l'investissement stratégique. Un processus analytique ou un environnement doit être développé pour permettre l'analyse comparative parmi des systèmes afin d'évaluer leur impact mutuel ou leur impact sur la capacité globale. Ce processus, désigné sous le nom de processus d'ingénierie des capacités (PIC), doit fournir la rigueur et la structure pour améliorer la synchronisation de la transition vers la capacité.

La Figure 3 illustre ces relations au niveau conceptuel. Le haut de la figure présente le processus actuel qui passe directement du concept de capacité à l'acquisition de composantes individuelles de systèmes, tandis que le bas de la figure propose l'introduction du IC pour fournir la rigueur et la structure à ce processus afin d'améliorer la synchronisation de la transition vers la capacité.

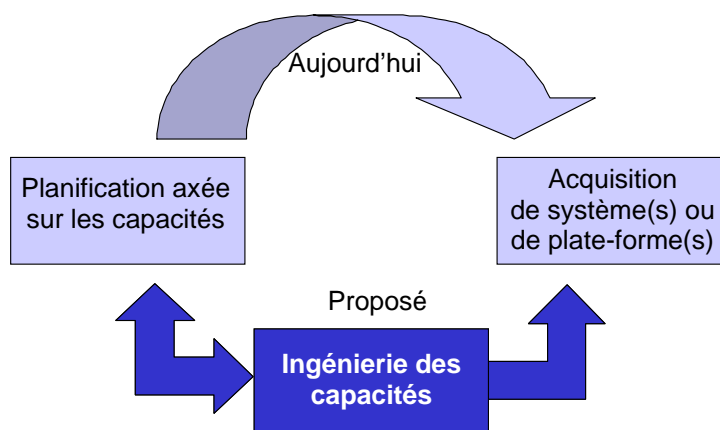


Figure 3 : Le IC dans le processus du PAC

L'application du IC exige un processus, des outils de support et le personnel avec les compétences pour les utiliser. Actuellement, la meilleure source pour puiser des processus et des outils est le domaine de l'ingénierie des systèmes (IngSys). La communauté associée possède des processus normalisés, utilise et améliore activement des outils dans le secteur de la gestion des besoins, la modélisation fonctionnelle, la modélisation d'architecture, la définition de cas d'utilisation, la conception assistée par ordinateur (CAO), la modélisation comportementale et les facteurs humains, la

modélisation du coût du cycle de vie et les simulations virtuelles autant que constructive. L'hypothèse de DIGCap est que ces processus et outils, qui sont normalement appliqués au niveau d'un système, peuvent être étendus au niveau d'une capacité (Système de systèmes - SdS) pour fournir la base pour le IC. Par conséquent, la définition de base du IC au début de ce projet est

«L'ingénierie des capacités est l'application de l'ingénierie au niveau système, de la gestion de processus et d'outils à la gestion de capacités afin d'établir la rigueur nécessaire pour la planification, l'acquisition et l'évolution efficaces des capacités dérivées de systèmes de systèmes »¹⁰

Le projet DIGCap a été établi pour définir le IC et pour valider la discipline dans le contexte canadien de la défense, en collaboration avec un éventail de parties prenantes du MDN et de l'industrie. La Figure 4 décrit le plan de travail du projet.

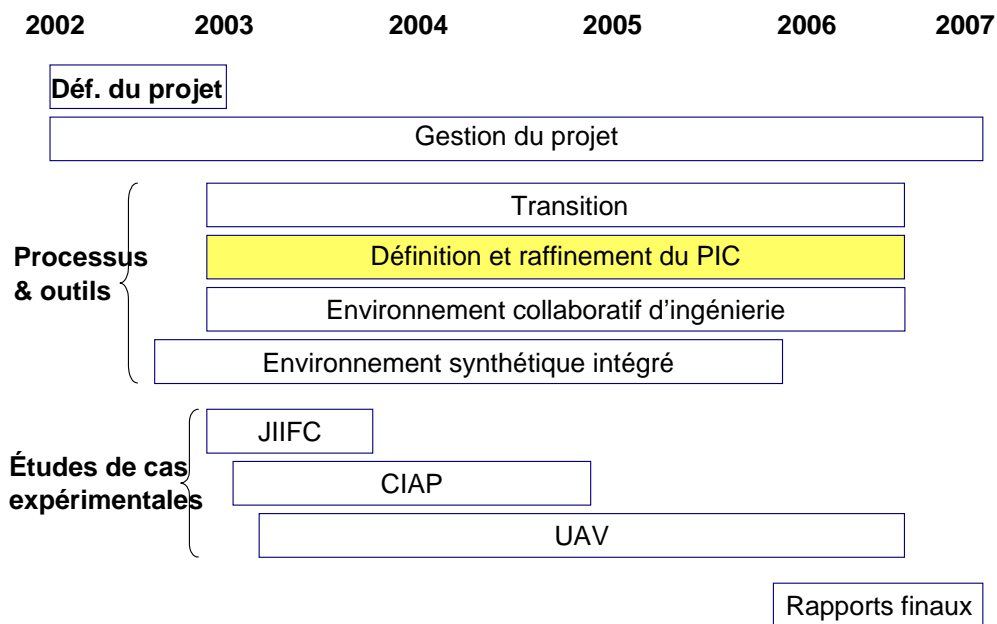


Figure 4: Plan de travail de DIGCap

Principales conclusions

Ce rapport résume le travail effectué par l'équipe du PIC d'avril à décembre 2003. L'objectif de l'équipe, pour le projet DIGCap au complet, est de livrer un PIC qui satisfait les besoins du MDN et des Forces canadiennes (FC). Le développement et l'évaluation du PIC seront exécutés en trois cycles d'une année chacun.

L'objectif spécifique de la première année (finissant en mars 2004) était de vérifier si le PIC et l'environnement collaboratif d'ingénierie (ECI) du Bureau américain de l'Ingénieur en chef (CHENG) placé sous le secrétaire auxiliaire de la Marine pour la Recherche, le développement et l'acquisition - également appelé ASN (RDA)

¹⁰ CapDEM Management Team, *Project Implementation Plan - Collaborative Capability Definition, Engineering and Management (CapDEM) Technical Demonstration Project*, 5 May 2003, 49 pp.

CHENG - sont un point de départ approprié pour DIGCap. L'équipe du PIC a utilisé, comme version initiale du PIC (PIC V0), un document écrit par M. Schmidt pour les besoins d'une équipe internationale (TTCP JSA TP4¹¹) et l'a employé pour les études de cas du cycle 1. L'objectif spécifique de ce premier cycle était de livrer un rapport d'évaluation intégrée de l'ébauche PIC de TP4 et des outils le supportant.

De la revue interne de littérature sur des sujets concernant le IC et l'analyse de l'ébauche PIC de TP4, les conclusions suivantes ont été tirées :

- En date de décembre 2003, le problème canadien n'a pas été suffisamment maîtrisé par l'équipe du PIC pour recommander ou proposer un PIC V1. La vue initiale de DIGCap et l'ébauche PIC de TP4 fournissent de bonnes définitions du « processus » et du « IC », mais des recherches supplémentaires sont nécessaires.
- Dans sa version actuelle, l'ébauche du PIC de TP4 est non applicable, puisque la documentation disponible est insuffisante. Beaucoup d'éléments, étapes et sorties ne sont pas assez clairs pour être utilisables. Trop de place est laissée à l'interprétation de l'utilisateur, ce qui pourrait mener à différentes réalisations pour le même genre de problème. Étant donné les limitations de l'information disponible, il n'est pas possible de déterminer si la carte de transformation résultante fournit toutes les informations pertinentes pour soutenir les décisions stratégiques d'investissement pour l'implantation des capacités du MDN/FC.

De plus, durant le cycle 1, l'équipe du PIC a identifié:

- La portée possible du IC: viser l'évolution, sur une période de quelques mois, d'une capacité basée sur une famille de systèmes de taille moyenne, pour une mission spécifique ou viser la création, sur une longue période de temps (5 ans), d'un SdS dédié.
- Les formes possibles du processus permettant le concept du IC examiné sous différents aspects: méthodologie (spirale, itérative, incrémentale, cascade, personnalisée...), niveau de raffinement (analyse des solutions de rechange versus matrice de Pugh, 1 livrable versus 20...), complétude (quoi, quand, qui, avec quoi (outils), critères d'entrée, critères de sortie, but et référence(s) pour chaque activité, entrée et sortie...); niveau d'adaptabilité à l'organisation (activités ou livrables, générique ou conçu en fonction d'une organisation...).
- Quelques solutions candidates déjà appliquées pour résoudre des problèmes semblables : l'acquisition militaire (acquisition évolutive, documents 5000 du US DoD, CJCSI¹² 3170...), l'ingénierie logicielle (RUP¹³, UML¹⁴...), IngSyS (IEEE 1220, ISO/IEC¹⁵ 12207, développement en spirale...), la description d'architecture (DoD AF, TOGAF¹⁶, Zachmann, architecture d'entreprise...).
- Quelques éléments dont il faut tenir compte pour le PIC V1:

¹¹ TTCP JSA TP4 - "The Technology Cooperation Program – Joint System and Analysis Group - Technical Panel 4 (Systems Engineering for Defence Modernization)"

¹² Chairman of the Joint Chiefs of Staff Instructions

¹³ Rational Unified Process

¹⁴ Unified Modeling Language

¹⁵ Internal Organization for Standardization/International Electrotechnical Commission

¹⁶ The Open Group's Architecture Framework

- Être adaptable c.-à-d. spécifier des livrables indépendants du contexte d'utilisation ou conçus en fonction de l'organisation (canadienne);
- Débuter par des approches standard et des références bien connues, telles que IngSys, l'ingénierie logicielle et l'architecture d'entreprise;
- Inclure une utilisation efficace de la modélisation et de la simulation, pour faciliter la réutilisation des données le supportant;
- Décrire les activités du processus avec un niveau suffisant de détail; et
- Limiter la place à l'interprétation c.-à-d. être explicite et compréhensible.

Développer un PIC: Principales questions qui nécessitent une réponse

Pendant notre revue de littérature, beaucoup de questions ont été soulevées, plusieurs abordent les problèmes présentés précédemment. Les principales questions sont énumérées ici:

- Le IC devrait-il permettre de construire des capacités virtuelles (existence de courte durée) autant que dédiées (existence de longue durée)?
- Le PIC devrait-il être concerné par l'auto-évolution, l'évolution jointe et l'évolution émergente (ou n'importe quel autre type d'évolution) d'une capacité?
- Le PIC est-il plus lié à la résolution de problèmes de gestion de l'ingénierie concurrente au lieu de problèmes de l'IngSys traditionnelle (mais complexe)?
- Pendant quelles phases du cycle de vie s'applique le IC?
- Quels sont les intrants et les extrants du PIC et qui utilisera l'information?
- Le PIC devrait-il être générique ou personnalisé à son contexte d'utilisation?
- Le PIC devrait-il envisager et proposer une solution composée de sous éléments d'une capacité (tels que DOTMLPF¹⁷ ou PRICIE¹⁸) ou être plus sélectif comme dans les stratégies 5000 d'acquisition?
- Puisqu'une capacité peut être définie à différents niveaux - technologique et commercial - de granularité, quels niveaux sont optimaux pour atteindre les objectifs du PIC?

Il n'est pas facile de répondre à ces questions au point où nous en sommes actuellement. Une bonne connaissance des besoins et des architectures actuelles est essentielle pour fournir un processus solide. Elle contribuera à l'identification des technologies qui formeront le PIC. Il est possible que le PIC lui-même ait un parcours différent d'un projet à l'autre. Par exemple, activités et notation peuvent différer selon le problème à résoudre.

Il est probable que la solution sera davantage dédiée à un ou des projet(s). Il peut être difficile de développer un PIC générique qui satisfera, dans l'avenir, tous les besoins en capacité. L'identification et la compréhension des technologies qui peuvent former

¹⁷ Acronyme du département de la Défense – États-Unis pour Doctrine, Organizations, Training, Matériel, Leadership, Personnel and Facilities,

¹⁸ Acronyme du MDN pour Personnel, R&D/Ops Research, Infrastructure & Organization, Concepts, Doctrine & Collective Training, IT Infrastructure, Equipment, Supplies and Services

le PIC sont des étapes importantes dans chaque projet. Il est, de plus, fortement probable que la nouvelle expertise devra être recueillie par des ingénieurs de systèmes afin de comprendre et adresser dans sa globalité tous les aspects inhérents à un PIC proposé.

Travaux futurs

Plusieurs questions restent en suspens avant d'établir le PIC. Bon nombre d'entre elles trouveront une réponse lorsque les besoins spécifiques de la communauté canadienne de développement de capacités et les problèmes réels d'acquisition seront identifiés. Certaines réponses proviendront de l'équipe du PIC qui se basera sur sa propre expérience et sur les ressources de conseillers. Finalement, d'autres viendront des compétences des parties prenantes à faciliter l'institutionnalisation et la priorisation des ressources. Puisque la portée du problème du IC est très vaste, une première solution devrait aborder seulement une partie du problème.

Basée sur la connaissance acquise pendant ces neuf premiers mois, la prochaine priorité pour l'équipe du PIC est d'obtenir une très bonne connaissance des manques actuels du processus canadien. Dans un premier temps, la situation présente canadienne « réelle » sera étudiée, en tenant compte principalement du processus actuel d'approbation des projets au sein du MDN. En plus, d'autres initiatives du MDN liées au PIC seront examinées. En parallèle, une sorte de situation actuelle internationale sera établie, regardant ce qui est fait à l'extérieur du Canada. De ces deux « situations actuelles » et des leçons apprises de deux études de cas de DIGCap intitulées, Intelligence et capacités communes de fusion de l'information (ICCFI) et Intelligence, surveillance et reconnaissance (ISR) maritime, PIC V1 sera élaboré et testé en utilisant des sous-ensembles de ces études de cas.

Bernier, F., Couture, M., Dussault, G., Lalancette, C., Lam, S., Lemieux, F., Lizotte, M., Mokhtari, M. 2005. CapDEM – Toward capability engineering process definition: A discussion paper. DRDC Valcartier TR 2004-230. R et D pour la défense Canada.

Table of contents

Abstract/Résumé.....	i
Executive summary	iii
Sommaire.....	viii
Table of contents	xiii
List of figures	xvi
1. Introduction	1
2. Background.....	3
2.1 The CE Concept	3
2.2 Mandate.....	5
2.2.1 Training on SysEng and ASN (RDA) CHENG Tools	5
2.2.2 Training on the ASN (RDA) CHENG approach.....	6
2.2.3 Practical Analysis with JIIFC.....	6
2.2.4 Literature Study	6
2.2.5 Theoretical Analysis.....	6
3. Perspectives on the CEP.....	8
3.1 Initial Perspective	9
3.1.1 US Naval Collaborative Engineering Environment (NCEE)	9
3.1.2 SoS and Complexity Issues	10
3.1.3 IEEE 1220	12
3.1.4 Role of the Life Cycle in the CE	12
3.1.5 Methodology and Process Model	14
3.1.6 DoD AF	14
3.1.7 Synthetic Environment Based-Acquisition (SEBA).....	15
3.1.8 Capability Based Planning	15
3.1.9 Discussion	16
3.2 TP4 CEP Working Draft Perspective	17
3.2.1 Discussion	22
3.3 Other Possible Perspectives.....	22
3.3.1 US DoD 5000 and Evolutionary Acquisition.....	22
3.3.2 Enterprise Architecture.....	24
3.3.3 Transformation Roadmap.....	25
3.3.4 Large Scale System Engineering Process (LSSEP)	26

	3.3.5	Discussion	27
3.4		CEP Team Understanding	27
	3.4.1	Candidate Solutions.....	27
	3.4.2	CE Scope	30
	3.4.3	Process.....	32
	3.4.4	Discussion	32
4.		TP4 CEP Working Draft: A Theoretical Assessment.....	33
	4.1	Strengths.....	33
	4.1.1	Standard Approach	33
	4.1.2	Known References	34
	4.1.3	Transformation Roadmap Definition	34
	4.1.4	Metrics Consideration	34
	4.1.5	Model-Driven	34
	4.2	Limitations.....	34
	4.2.1	US Specificity.....	34
	4.2.2	Overall Schematic View.....	35
	4.2.3	Scope and Intention	35
	4.2.4	Boundary and Context.....	35
	4.2.5	Activity Description	36
	4.2.6	Requirements Management.....	36
	4.2.7	CEP Figure	36
	4.2.8	Glossary References and Definition.....	37
	4.3	Qualitative assessment.....	37
	4.4	Applicability	39
5.		TP4 CEP Working Draft: A Practical Assessment through JIIFC Case Study	40
	5.1	The JIIFC Project	41
	5.2	The JIIFC Concept Definition Process.....	41
	5.2.1	Operational Analysis as a Trigger	42
	5.2.2	Activity 1: Define Context and Boundary	44
	5.2.3	Activity 2: Analyze Requirements	44
	5.2.4	Activity 3: Model Current Environment	45
	5.2.5	Activity 4: Analyse Gaps.....	46
	5.2.6	Activity 5: Evaluate Alternatives	46
	5.2.7	Activity 6: Select Future Architecture for Implementation.....	46
	5.3	The JIIFC Engineering Environment	47
	5.4	Lessons learned	48
	5.4.1	Results from the JIIFC Workshop.....	48
	5.4.2	The Application of TP4 CEP Working Draft	48

6.	Conclusion.....	51
7.	References	53
	Annexe A.....	58

List of figures

Figure 1: CE in the CBP Process.....	iii
Figure 2: CapDEM Work Streams	iv
Figure 3 : Le IC dans le processus du PAC	viii
Figure 4: Plan de travail de DIGCap	ix
Figure 5: CE is One Domain of Capability Management (from [12]).....	3
Figure 6: CE in the CBP Process (from [12]).....	4
Figure 7: CapDEM Work Streams as of December 2003	5
Figure 8: System Life Cycle (SLC) from Lust to Dust is this figure extracted from one of the reference? (Modified from [5], p. 6)	13
Figure 9: Systems and Capability Management [86]	16
Figure 10: TP4 CEP Working Draft Activity Breakdown (from [58]).....	19
Figure 11: TP4 CEP Working Draft Activity Breakdown versus Time (from [58])	20
Figure 12: TP4 CEP Working Draft Interpretation	21
Figure 13: Enterprise Architecture Layers (from [54])	24
Figure 14: LSSEP Presentation (from [73])	27
Figure 15: Candidate Solutions from Different Perspectives	28
Figure 16: The Characteristics of a Current Capability, the Nature of CEP and the Characteristics of a Future Capability Influencing the Scope of the CE.....	31
Figure 17: Process Scope.....	35
Figure 18: Capability-Based System Acquisition Process	37
Figure 19: JIIFC Concept Definition Process.....	43
Figure 20: JIIFC Requirements Schema.....	45

List of tables

Table 1: Qualitative Assessment	38
Table 2: TP4 CEP Working Draft Activities Addressed with the JIIFC Case Study (2003) ...	40
Table 3: Analysis of the TP4 CEP Working Draft as Applied to JIIFC.....	50

1. Introduction

The Department of National Defence (DND) is currently implementing Capability Based Planning (CBP) as a core element in its overall business process. Once defined by the CBP, a capability must be managed and more particularly engineered. The Collaborative Capability Definition, Engineering, and Management (CapDEM) Technology Demonstration Project (TDP) aims at defining Capability Engineering (CE) and validating the discipline in the Canadian defence context, in collaboration with a wide range of DND and industrial community stakeholders. An important part of this project consists of defining and refining a Capability Engineering Process (CEP) meeting DND/CF's needs. As with many other work streams in this TD, the development and evaluation of the CEP will be performed in three one-year cycles during the course of the project.

The report summarises the work conducted by the CEP Team from April 2003 to December 2003. The specific objective for the first year (ending in March 2004) was to verify if the CEP and Collaborative Engineering Environment (CEE) of the US Office of the Chief Engineer (CHENG) under the Assistant Secretary of the Navy for Research, Development, and Acquisition – also called ASN (RDA) CHENG - are a suitable starting point for the project.

Section 2 introduces CE, a key concept under investigation within CapDEM TDP. CE aims at improving decision-making for strategic investment through an analytical process or environment. Trade-off analysis can be conducted across systems to evaluate their overall impact on each other or on the overall capability needs to be developed. This process referred as the CEP should provide rigour and structure to enhance capability synchronization transitioning. In addition, Section 2 summarises the CEP Team mandate and its execution from April 2003 to December 2003. The team has structured its effort around the ASN (RDA) CHENG approach that was considered to be a suitable starting point for the Canadian investigations. The main activities, events and decision points are presented in chronological order.

Section 3 presents several perspectives of the CE (CEP) reflecting the evolution in understanding by CEP Team of what is or what would be CE (CEP). CE is a new concept within DND and the understanding that people have of it is currently limited. Each perspective is presented according to some aspects such as possible scopes and specific objectives, candidate solutions and process forms. A first perspective is given by CapDEM TDP documents [9][12], which propose many candidate solutions as part of the CEP. Instead of opting for the development of a completely novel CEP of its own, DRDC decided to build on an existing construct by evaluating the efforts of an international team (TTCP JSA TP4¹⁹). This second perspective is referred in this report as TP4 CEP Working Draft and is described in the document entitled “Overview of the Capability Engineering Process” produced in June 2003 [75]. The third part of Section 3 is dedicated to the review of technologies which could complete the two previously

¹⁹ TTCP JSA TP4 stands for “The Technology Cooperation Program – Joint System and Analysis Group - Technical Panel 4 (Systems Engineering for Defence Modernization)”

perspectives. Finally, the last part of Section 3 synthesizes information and presents an integrated version of all presented perspectives.

Section 4 presents an analysis of the TP4 CEP Working Draft. The analysis is based on two independent theoretical efforts: an internal DRDC effort conducted by defence scientists and a parallel one conducted by contracted consultants. The analysis is divided into four aspects: strengths, limitations, qualitative assessment and applicability. The presented strengths are rather high-level observations while the limitations are more specific observations. This analysis summarises, as of December 2003, the thoughts of the CEP Team about the TP4 CEP Working Draft based on available (documented) details at that time. The section ends by a conclusion of the applicability of TP4 CEP Working Draft for use by DND.

Section 5 describes the application of the TP4 CEP Working Draft using the Joint Intelligence and Information Fusion Capability (JIIFC) as a use case. The goal of the use case study was to gain practical experience on the TP4 CEP Working Draft. This case study allowed the CEP Team to evaluate the TP4 CEP Working Draft from a practical perspective through “hands-on” experience. Section 5 captures lessons-learned on the analysis and adaptation of the process and on the application of the CEE to support JIIFC concept definition activities. As a CapDEM activity, the scope of this use case study focused mainly on the application and analysis of the TP4 CEP Working Draft and the CEE. Nonetheless, the CEP Team worked closely with JIIFC project team to ensure the work being carried out met the requirements of both the CapDEM and JIIFC projects.

Finally, the report concludes by evoking important points to retain and introduces some thoughts on the way ahead.

2. Background

CE is a key concept under investigation within the CapDEM TDP; it aims at improving decision-making for strategic investment. The CEP Team has the mandate to explore such a process to assess its viability at meeting DND/CF's requirements. As a first phase in the execution of this mandate, the team has structured its effort around examining the RDA CHENG approach. The following sections:

- Introduce the concept;
- Describe the CEP Team mandate; and
- Summarise its execution until December 2003.

2.1 The CE Concept

The DND is currently implementing CBP as a core element in the overall business process. Once a capability is defined it must then be managed. Capability Management considers a number of sub-domains including Capability Development and Improvement, Capability Employment and Operation, and Capability Sustainment. CE is primarily focused on the development and improvement domain as illustrated in Figure 5.

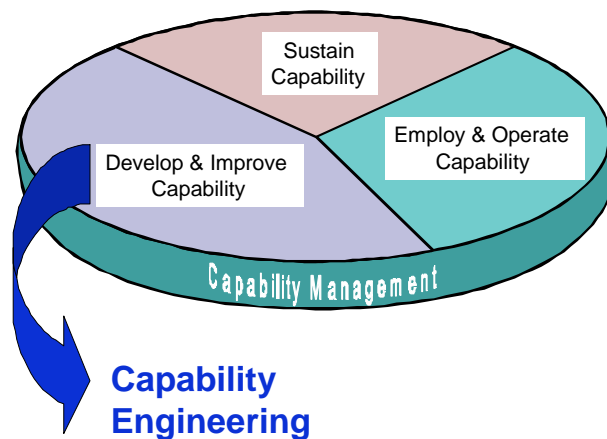


Figure 5: CE is One Domain of Capability Management (from [12])

Currently in DND the CBP process leads to the acquisition of systems within that capability. However, there is not a systematic link between the conceptualization of a capability and the detailed definition of the component systems, nor is there an analytical process or environment where trade-off analysis can be conducted across systems to evaluate their overall impact on each other or on the overall capability. In order to “systematize” this capability development process the rigour of the System Engineering (SysEng) process is required. Figure 6 illustrates these relationships at the conceptual level, whereby the top of the figure indicates the current process of

“leaping” from capability concept to individual component system acquisition, and the bottom of the figure proposes the introduction of a CEP to provide rigour and structure to that process so as to enhance capability synchronization transitioning.

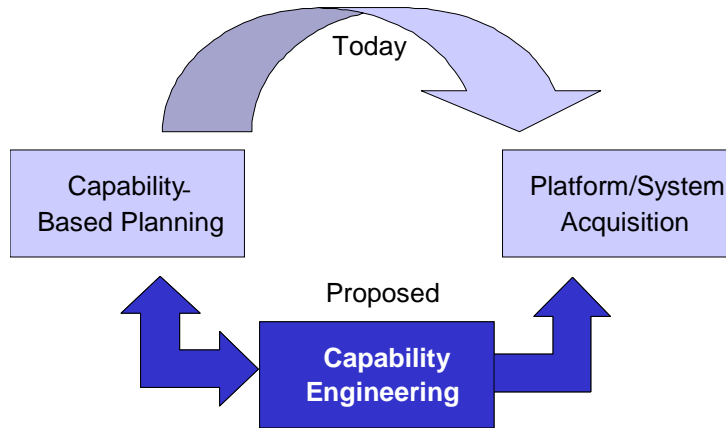


Figure 6: CE in the CBP Process (from [12])

The application of CE requires a process, supporting tools, and personnel with the skill sets to employ this process and tools. The best source for processes and tools at this time is the SysEng domain, whereby the community has standardized processes and are actively using and enhancing tools in the area of requirements management, functional modelling, architecture modelling, use case definition, Computer Aided Design and Drafting (CADD), human form and behaviour modelling, life cycle cost modelling, and both constructive and virtual simulation. CapDEM’s hypothesis is that these processes and tools, which are normally applied on a system level, can be extended to the capability (System-of-Systems - SoS) level to provide the basis for CE. As a result, the baseline definition of CE at the start of this TD is:

“Capability Engineering is the application of system level engineering and management processes and tools to Capability Management in order to establish the necessary rigour for effective planning, acquisition and evolution of a system-of-systems capability”²⁰

The CapDEM TDP has been established to define CE and to validate the discipline in the Canadian defence context, in collaboration with a wide range of DND and industrial community stakeholders. Figure 7 outlines the project work plan.

²⁰ [12] p. 3

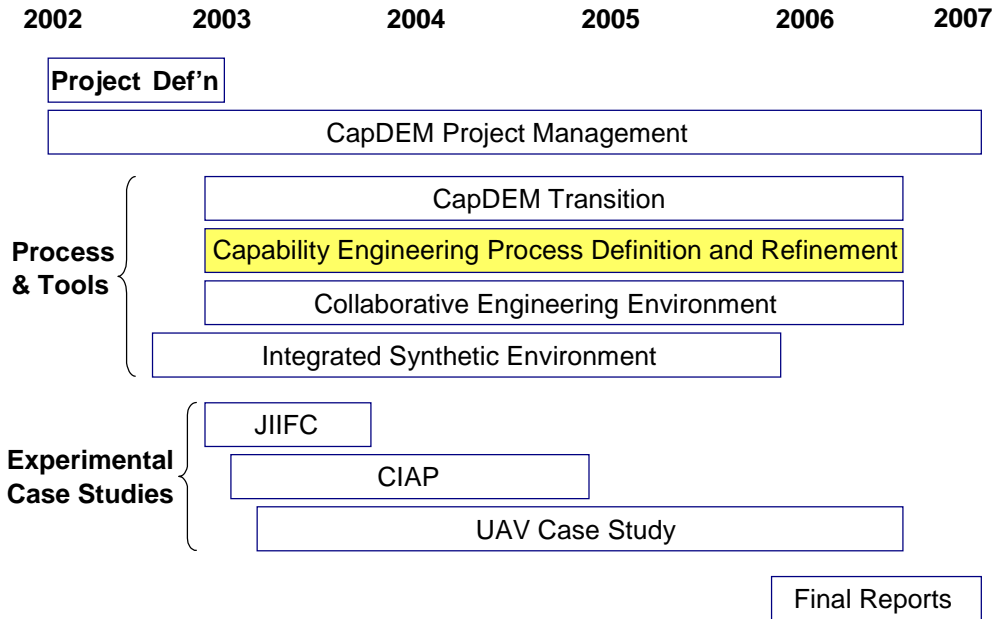


Figure 7: CapDEM Work Streams as of December 2003

2.2 Mandate

The current report summarises the work conducted by the CEP Team from April 2003 to December 2003. The objective of this team, for the whole CapDEM project, is to deliver a CEP that meets DND/CF's needs. As with many other work streams in this TD, the development and evaluation of the CEP will be performed in three one-year cycles during the course of the project.

The initial CEP plan for the first cycle (April 2003-March 2004) is based on the following assumption, described in the CapDEM Project Implementation Plan (PIP) [12]: The approach of the US ASN (RDA) CHENG is a suitable starting point for the Canadian investigations, and these tools will be straight forward to install and integrate on DRDC/DND information networks. The CEP Team considered this approach as the CEP V0 to be used for case studies in the first cycle. The specific objective for this first year is to deliver an integrated assessment report about this approach.

The following subsections describe the execution of this mandate by summarising the main activities, events and decision points.

2.2.1 Training on SysEng and ASN (RDA) CHENG Tools

As planned, the project started in April 2003. Two customised training courses on SysEng were given, a first one by Dr Denis Laurendeau [57], a professor of Laval University and a second by Mr Richard Schmidt [76] from Systems Technology, Inc., a consultant under contract by RDA CHENG. In addition, some team members attended the INCOSE 2003 conference [71]. Many members also had training on the main tools used by RDA CHENG approach i.e. DOORS by Telelogic [78], CORE by Vitech Corporation [85], and Interchange by Trident Systems Inc [80].

2.2.2 Training on the ASN (RDA) CHENG approach

The CEP mandate being to evaluate the ASN (RDA) CHENG approach and supporting tools, the most important training course was given to CEP Team members by Mr. Richard Schmidt, a senior systems engineer consultant who is intimately familiar with the ASN (RDA) CHENG approach, who defined the key process and toolsets. The course brought a good opportunity to have interesting exchanges about SysEng; it was very useful for the CEP Team at this stage but lack details about how to apply the ASN (RDA) CHENG approach.

From previous discussions and presentations, it was known that this approach was based on Department of Defence Architecture Framework (DoD AF) [28][29][30] (formerly C4ISR AF) and IEEE 1220 [44]. Following discussions with Mr. Schmidt, the team understood that US Defence industry has asked DoD to stop mandating a process in the RequEst For Proposals (RFPs); DoD did so. Now instead of imposing a specific process, DoD requires specific deliverables specified in DoD AF and leaves industry to decide for itself, which specific systems engineering processes will be used to produce them most effectively. There is also no notation mandated within DoD AF but they are giving guidelines on Unified Modeling Language (UML) usages [74][81].

Following this training, Mr. Schmidt provided to the CEP Team a document entitled “Overview of the Capability Engineering Process” in June 2003 [75] through the TTCP JSA TP4. This document was the most relevant document available to examine the ASN (RDA) CHENG approach. This document is referred in this report as TP4 CEP Working Draft.

2.2.3 Practical Analysis with JIIFC

The CEP Team started by using the TP4 CEP Working Draft, the IEEE 1220 and DoD AF to validate the CEP with the JIIFC case study. This experimentation allowed the team to evaluate the first activity of TP4 CEP Working Draft proposal, the “as-is” architecture of JIIFC, from a practical perspective [22]. Lessons-learned through this “hands-on” experience were collected on the analysis and adaptation of the process as well as on the application of the RDA CHENG tools.

2.2.4 Literature Study

In order to learn about the subject under study and in addition to the training, the CEP Team conducted a literature study covering SoS, SysEng standards, Simulation-Based Acquisition (SBA) and US acquisition. This study was performed in two phases separated by a workshop investigating the TP4 CEP Working Draft. The workshop raised some new elements to investigate.

2.2.5 Theoretical Analysis

The CEP Team conduct a theoretical analysis of the TP4 CEP Working Draft. Two independent assessments were conducted to get different viewpoints. A

consultant, Mr Jocelyn Leclerc from CGI, was asked to examine the process based on his industrial experience and theoretical knowledge [58]. In addition, the CEP Team held a workshop²¹ to make its own viewpoint on the process. After this analysis, R. Schmidt was invited to clarify some elements in order to complete the theoretical analysis (see Annexe B).

²¹ This two-days workshop was held at DRDC Valcartier in September 2003 (11-12 sept.).

3. Perspectives on the CEP

The CE construct is a new concept that aims at setting up and improving military capabilities in the CF. Reaching this final objective implies improving actual capability acquisition approaches that suffer from a number of inefficiencies. The underlying problems of the actual acquisition approach must be solved. However, the CE concept cannot improve every aspect or solve all underlying problems related to capability acquisition. Investigations showed that opportunities to improve capabilities are numerous. Consequently, the scope of intervention of the CE must be identified first, and then a solution must be proposed to solve a specific problem corresponding to portion of the scope. This choice will then define specific objectives of the CEP and not only its final objective.

At the beginning of the project, there was a unique perspective of the CEP. This perspective was described in the CapDEM TDP documents [9][12] and technologies referred by these documents. An initial understanding of CEP has been built on this perspective. At the time of writing this document, the possibilities for CEP are still numerous. Next to this initial understanding of CEP, it was decided to select a process being analyzed by the TTCP JSA TP4 group and to evaluate it. An analysis of this process showed clearly many differences between the initial perspective and the one resulting from TP4 CEP Working Draft. The latter introduced many new concepts and references, all aimed at improving capability. These elements increased considerably the degree of understanding of CEP. Since there was no longer a single perspective of CEP, further investigations have been done to identify the most relevant elements linked to CEP. These investigations showed there exists many potential perspectives of the CEP concept.

This section reflects the change in understanding of CEP, mostly based on understanding of technologies related to CEP. The first part of this section is organized around three subsections, each one representing a perspective (or a major step in the project) of CE and its process²²: the initial project perspective (Subsection 3.1), the TP4 CEP Working Draft analysis perspective (Subsection 3.2) and, finally, the perspectives resulting from further investigations (Subsection 3.3). Our hypothesis is that piecing together all these views will define a global and coherent understanding of the possibilities of CEP. Based on this understanding a solution can be chosen within this scope.

Each subsection describes CEP according to the following aspects:

- **Possible Scopes and Specific Objective:** our investigations identified many possible versions of the concept of CE. Most of these interpretations of CE are valid since they contribute to the set up and improvement of military capabilities in the CF. The possible scopes aspect will help to identify all possible scopes of the CE, all of them able to contribute to the same final objective. With all the possible scopes defined, it will be possible to choose a scope for CE. This scope

²² CE is a concept implemented by tools, people and processes. This section focuses on process to implement the concept. This distinction is important and will help to raise questions.

will help to define the specific objective of the CE. This scope will also help to delimit the boundaries of the problem and the solution space of the CE concept.

- **Candidate Solutions:** Many existing approaches, standards, processes, tools etc., have been proposed or already applied to similar problems. These candidate solutions can all be used to develop and enrich the CEP. These technologies will be reviewed and be put into context.
- **Process Forms:** Concepts may remain theoretical if they are not applied. A rigorous methodology can crystallize this concept. It is called a process. Even if most people agree on what is a process, there is no universally accepted form of a process. The reason is that a process is tailored for every specific domain. This activity requires time and effort. Therefore, every possibility for the process form should be determined in order to plan a process development strategy over a feasible schedule.

Each perspective will raise many questions in regard of these aspects. These questions will be highlighted by a box inserted in the text. Finally, Subsection 3.4 synthesizes the information presented in the previous subsections and presents candidate solutions, possible scopes, specific objectives and process forms. This integrated version is the basis that was used to understand the details of a CEP.

To sum up, the outcomes of this section will be to:

- demonstrate that the initial project view and the TP4 CEP Working Draft had a good but too limited (or too concise) definition of a process and CE.
- determine the possible dimensions of the scope in the CE, the possible form of the process enabling this concept and the specific objectives of the CE.
- present some candidate solutions that are already used in the solving of similar problems.

3.1 Initial Perspective

The first perspective of CEP is the one described partially in the definition of the CapDEM TDP: the initial version of the Project Charter [9] and the PIP [12]. Although the description is focused on the definition of the project, both documents help to understand CEP. These documents already propose many candidate solutions as part of the CEP. The initial perspective also includes the understanding of CEP from SysEng and SoS literature. The following paragraphs present these candidate solutions or domains and try to define the previously mentioned aspects for CEP.

3.1.1 US Naval Collaborative Engineering Environment (NCEE)

Firstly, the US NCEE is an important enabler for the concept of CE. It “enables a multi-disciplinary development team to address all engineering activities in a comprehensive and integrated manner” [12]. The NCEE actually integrates many commercial engineering tools: DOORS [78], CORE [85], Interchange [80] and Rational Rose [43]. These tools support many activities of SysEng. The NCEE relies on the efficient use of these tools to improve the development of a capability. It cannot be defined independently

of the process. Ideally, a process should not be tailored to fit with a specific toolset. However, limitations of tools could limit the usability of the process. Inversely, the toolset should support the process.

Do the NCEE tools represent the best configuration to support the CEP?

3.1.2 SoS and Complexity Issues

The PIP refers to the concept of “Capability as a SoS”. It defines the SoS as “an assemblage of components which individually may be regarded as systems and ...” and have a managerial and operational independence. SoS [15] implies the study of the complexity underlying the development and the use of multiple collaborative systems. Since a capability is the result of merging one or more system(s), this field requires to be examined carefully in CEP. The link between a capability and a SoS is not clear.

It is not clear at which level a SoS becomes a synonym for capability, assuming that the two can be compared?

The answer to this question is partially related to the definition of a system. For instance, the IEEE 1220 defines a system as “a set or arrangement of elements (people, products -hardware and software- and processes -facilities, equipment, material, and procedures-...”²³ If a system includes people, products and processes, the meaning of a SoS get closer to the meaning of a capability. However, other elements not specifically pointed out by this definition should be also included in a capability.

Further reading [60] on SoS issues have shown that SysEng could build or evolve various types of SoS. For instance, large-scale component systems can be specifically designed to work together. This type of SoS, called *dedicated*, is constructed over a long period of time. Another type of SoS, called *virtual*, can be created to support specific military operations. In a *virtual* SoS, the various systems are not designed initially to be integrated. These SoS are generally constructed in a short period of time to meet specific mission requirements and are dismantled after the operation. Cook [20] claims that it is essential to make a distinction between these two since the acquisition imperatives for each type are different. Some of these systems are also referred to as Family-of-Systems²⁴ (FoS) and federation-of-systems. These terms remain to be studied.

²³ [44] p. 10.

²⁴ A “family-of-systems” is a set or arrangement of independent (not interdependent) systems that can be arranged or interconnected in various ways to provide different capabilities. The mix of systems can be tailored to provide desired capabilities according to the mission. Under today's warfighting, assembly of forces for contingencies is primarily ad hoc, based on a generic set of requirements rather than preplanning that designates specific forces for a particular contingency. Thus, interoperability of the independent platforms is a key consideration in the ad hoc deployment of a “family-of-systems” [40].

Should CE be able to construct virtual (short-term time frame) and dedicated (long-term time frame) capabilities?

The way that a SoS evolves is another important concern for CEP. For example, Chen and Clothier [15] identified three types of evolution for a SoS: *self-evolution*, *joint evolution* and *emergent evolution*. The first type goes through the evolution of a system (part of the SoS) without changing any interface of others systems. The second type refers to the integration of two or more systems (part of a SoS) to improve interoperability and business support. Finally, the *emergent evolution* designates the development of a new system “on the basis of or in relation to existing systems with new functionalities or capabilities.” [60]. This list is by no means complete.

Should CEP be concerned with self-evolution, joint evolution and emergent evolution (or any other types of evolution) of a capability?

Chen and Clothier [15] also suggest that SoS SysEng cannot be limited to the traditional SysEng issues at the development level. The authors assert that the SoS SysEng should deal with managerial complexity (for instance, support of concurrent engineering). This complexity can represent itself as an engineering issue.

Is CEP more related in solving these managerial issues of concurrent engineering instead of traditional (but complex) SysEng issues?

The complexity issues inherent to SoS and capability have been discussed in numerous documents. For instance, some papers [3][53][64] have analysed and proposed some solutions or advices that help to deal with such complexity. The challenge is to decompose the problem into smaller (and simpler) parts while preserving the global vision and complex interrelations. CEP should look at these solutions.

The new way of doing engineering [15][20][3] in the context of SoS imposes an important change (or an evolution) of the traditional SysEng approach. This approach consisted of dividing a relatively complex problem into smaller problems that were simpler to solve individually. Then, all sub-solutions found were put together into a global solution without systematically considering links and effects between these solutions. This method resulted in a so-called reductionist way of finding solutions. The global solution was good for highly deterministic systems that are non autonomous (or that are dependent of the whole to have a life). It is probably inadequate for SoS involving non-deterministic behaviours with independent systems (that may have a life apart from the whole SoS).

For the new paradigm inherent to SoS, the independent systems must collaborate to provide the needed capability. This collaboration involves complex exchanges of information that may cause complex behaviours within the SoS. A holistic approach giving a global view of the whole SoS is thus

needed to allow the understanding of complex behaviours. This implies the consideration of all factors (or elements of information) and links between them that may affect the whole SoS (or capability).

There is a scoping problem with this new holistic approach. For complex and large SoS, it is not possible to consider all factors and links. The reason is that the number of these factors and links between them is too high (for the human brain and for actual CASE tools). A trade-off analysis is thus needed (within this holistic context) to define and establish a strategic scope that will bring the number of factors and links to an acceptable level, while still allowing the SoS to provide the needed capability. The scope would keep only the factors and links that may have a medium-to-strong impact on the act of providing the capability. This “medium-to-strong” threshold will always depend on the efficiency of the SoS to deliver the capability. The greater efficiency needed, the lower the threshold will have to be and thus the greater number of factors and links will have to be considered.

What are the elements within the CEP that will help the trade-off analysis for the identification of all important factors and links that should be taken into account?

3.1.3 IEEE 1220

The IEEE 1220 SysEng process [44] is another potential solution that has been investigated. As described in the process definition document, “this standard defines the requirements for an enterprise's total technical effort related to development of products (including computers and software) and processes which will provide life-cycle support (sustain and evolve) for the products.” Consequently, this process enables best practices and rigorous methodology to develop, sustain and evolve single system. Since a capability is based at least on one system, such approach might contribute to help at setting up and improving military capabilities. In the case where a capability results from the collaboration of many systems (SoS), chances are that this standard process should be updated. This process is a potential solution that could be adapted to the capability context.

Based on the analysis of the 1220, investigations turned towards others enhanced development methodology (spiral, incremental, iterative, waterfall, etc.) and others SysEng processes (ISO/IEC 12207 [47], EIA 632²⁵ [39]...) and theories [5].

3.1.4 Role of the Life Cycle in the CE

The definition of the CE is strongly related to the life cycle of systems participating in the capability and to the life cycle of the capability itself.

Figure 8 illustrates the possible phases by which a system can undergo.

²⁵ [77], this paper shows the processes of EIA 632 in Figure 2.

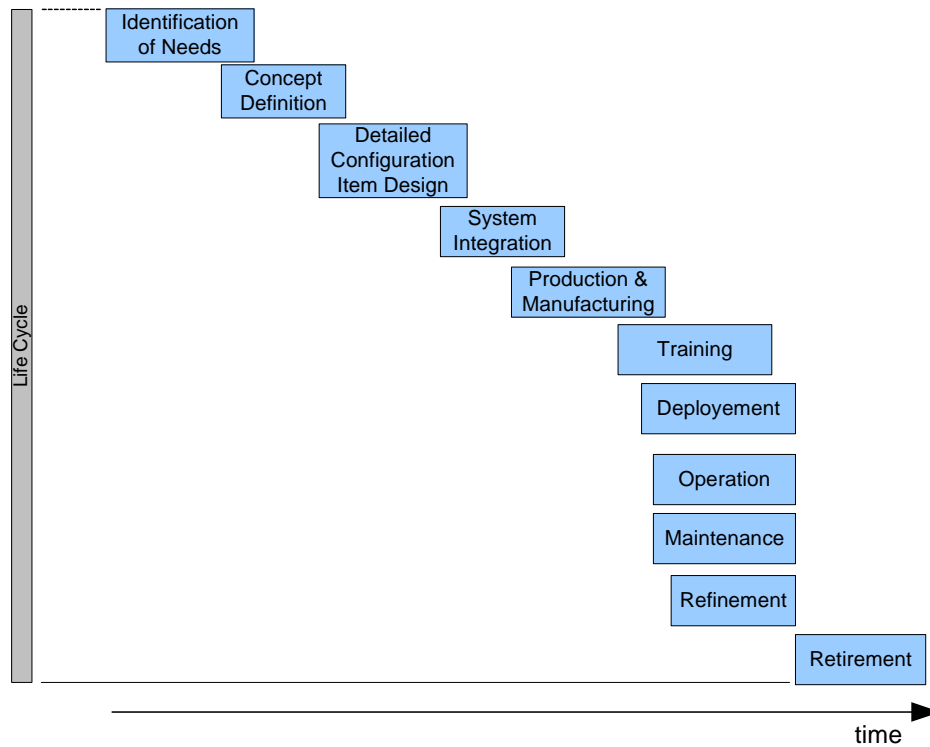


Figure 8: *System Life Cycle (SLC) from Lust to Dust is this figure extracted from one of the reference? (Modified from [5], p. 6)*

The relation of the life cycle with the CE is twofold. On one hand, the CE can consider only some phases of the life cycle of the constituent systems and of the capability itself. For instance, taking into account considerations like disposal, maintenance, manufacturing and training could result in a slightly less performing system in the battlefield but could increase greatly its maintainability, training, disposal and so on. The performance on the battlefield and the initial purchase cost are not anymore the only variables to optimize in the design. In order to apply good engineering practices, all phases of the life cycle should be considered. However, the cost to consider all of them could be too prohibitive. Resources and time limitations will lead to a trade-off.

Should the trade-off between different phases be the art and science of CE?

On the other hand, the CE can be applied²⁶ during all or some part of the life cycle of a capability²⁷. As illustrated in Figure 8, the SysEng does not address all phases of the life cycle. As for the SysEng, the CE can only go through some of these phases. For instance, the CE could be involved only in

²⁶ The difference between “consider” and “be applied” is fundamental here.

²⁷ The term life cycle of a capability refers to the phases of the elements related to a capability like the included systems or the management activities.

the concept definition phase²⁸ and could leave the detailed configuration item design to traditional SysEng.

During which phases of the life cycle the CE is applied?

The nature of a capability in relation to the systems supporting it will influence the answer to these two questions. Assuming a capability includes a single system, the life cycle of a capability would be equivalent to the life cycle of this system²⁹. However, in the case that a capability includes many systems (SoS), the capability life cycle would not necessarily follow these phases. If all systems composing the capability were created from scratch (but even having an operational and managerial independence), the life cycle of the capability might be approximately the same life cycle as all included systems. In cases where a capability already included many systems, the phases would be partially related to the introduced (one to many) systems to the existing systems and to the capability creation itself.

3.1.5 Methodology and Process Model

Another important element to consider for CEP is the methodology, or process model [14] used to develop the systems. To name a few, the spiral, incremental, iterative and waterfall models are all examples of methodology. Depending on the organizational environment and the nature of the application, different process models will be required. These process models can be applied at two levels: on the capability development (or evolution) itself³⁰ and on the development of underlying systems. If the organizational environment and the nature of application are similar for most capabilities, CEP could support a single (optimized) process model. Otherwise, this decision could be left to individual organization. It would be possible to choose the most adapted methodology to each capability context.

Should CEP be tailored to an optimal process model?

3.1.6 DoD AF

DoD AF [28][29][30] is an architecture framework that could facilitate the conception, the development, the improvement, and sustainment of capabilities. It is described as follows: “The DoD AF, Version 1.0, defines a common approach for US DoD architecture description development, presentation, and integration. The framework is intended to ensure that architecture descriptions can be compared and related across organizational boundaries, including Joint and multinational boundaries.”. This framework is based on 4 related views of architecture: Operational Views (OV), System

²⁸ Interoperability considerations between systems would be managed in this phase in this example.

²⁹ The veracity of this assertion depends of what is engineering to get (or improve, update) a capability.

³⁰ The capability development methodology can be replaced by acquisition strategy. The latter will be presented in the Subsection 3.3.

Views (SV), Technical Views (TV), and All View. These views contain graphical, tabular, or textual representation of architecture information. The DoD AF is based on a data model called the Core Architecture Data Model (CADM) [68]. CADM defines the data structure and relationship for architecture information.

This technology is useful to describe both hardware and software architectures. It can improve the interoperability of the various systems participating in the capability. Therefore, the architecture-oriented approach is a candidate approach that could be part of CEP.

3.1.7 **Synthetic Environment Based-Acquisition (SEBA)**

SEBA is another important concept³¹. Introduced in the PIP, the SEBA project objectives were to “define, implement and demonstrate how a synthetic environment can be used to provide an integrated concept development and experimentation capability to support faster/better/cheaper acquisition decisions.” [12]. Even if the approach is different, these objectives are similar to the CEP objectives. Consequently, the SEBA-like³² concepts would play an important role in reaching the CEP objectives. Like for the NCEE, CEP will probably have to be adapted in order to enable the SEBA-like concepts. Moreover, these concepts will have to be adapted to CEP.

What role might SEBA play in CEP?

3.1.8 **Capability Based Planning**

The CBP concept [86] is strongly related to CE. “The concept recognizes the interdependence of systems (including materiel and people), doctrine, organization and support in delivering defence capability, and the need to be able to examine options and trade-offs among these capability elements in terms of performance, cost and risk so as to identify optimum force development investments.”³³. This concept includes other enabling technologies like SMARRT and CDE. It also recognizes the importance of SysEng and its toolset (like NCEE) “to support the rigorous examination of the issues that drive system performance and integration at sufficient detail to enable system implementation.”³⁴. This definition is closely related to the concept CE defined in the PIP: the CE should help to ‘systematize’ the capability development process by adding the rigour of the SysEng process between CBP and the acquisition. Many questioning about the relation between CE and CBP have been raised. It has been concluded that the relationship between all these elements is not temporal but conceptual, i.e. CE

³¹ SEBA is the name of a Canadian project (before CapDEM), and, also, the name of the UK concept.

³² Simulation and Modeling for Acquisition, Requirements and Trainning (SMART), Simulation and Modeling for Acquisition, Requirements, Rehearsal and Trainning (SMARRT) and SBA are similar initiatives.

³³ [86] p. 2.

³⁴ [86] p. 4.

does not follow CBP. However, the question of whether CE is used during the acquisition phase (temporal relationship) remains to be answered.

Is the relation between the CBP and CE conceptual or temporal? Can CE take place during the acquisition?

As mentioned previously, a capability could be the integration of many existing systems. These systems can be at different phases of their life cycle. Figure 9 shows an example of a capability built on many existing systems.

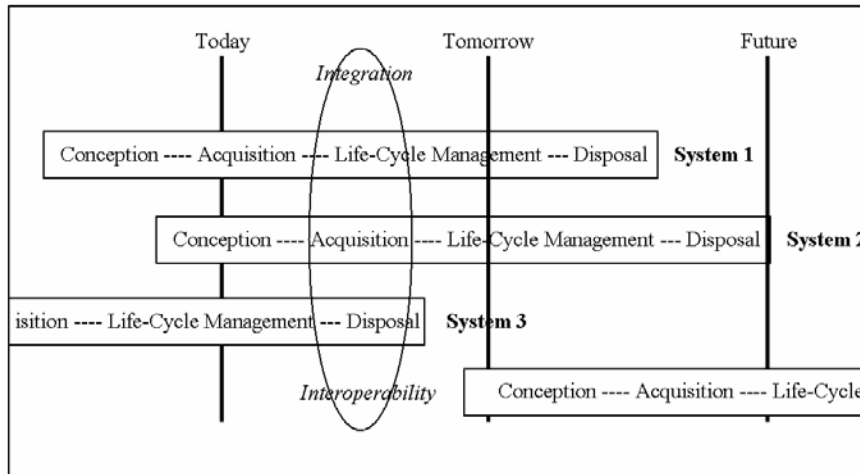


Figure 9: Systems and Capability Management [86]

The synchronization and replacement of these systems to maintain or improve a capability will be a challenging issue. However, if the role of CEP is to enable this kind of capability, it is not clear what are the specific responsibilities of CEP to reach this objective.

Does the CE choose among existing systems to create a capability, or is this role dictated by the CBP or the Capability Management?

In the latter case, if the system is chosen by the CBP, the CE's responsibility would be to create or sustain compatibility among existing systems (for the doctrinal, material and/or training aspect) and would plan (or develop) the interoperability of the new added system(s). If the CBP is a concept only and not a step in the development of a capability, CE could be its implementation and there is no contradiction. Otherwise, overlap between the CE and the CBP remains to be clarified.

3.1.9 Discussion

In summary, the initial perspective on CEP already includes many solutions. Should CEP be created from all these solutions? Is there any gap, overlap or contradiction between these solutions? When piecing together most of these technologies, the project description and the actual possible scopes, our

understanding of the CEP specific objective will be to adapt engineering methods, traditionally used in a system context, to create SoS. In this initial perspective, a capability is roughly a synonym of SoS. CEP is a kind of enhanced IEEE 1220, ISO/IEC 12207 or Rational Unified Process (RUP) [56][42] adapted to SoS context. The process takes into account all life cycle phases (ex: manufacturing, deployment, training, maintenance, disposal) and is applied during most of the SysEng life cycle (detailed design, integration, production and manufacturing) to create a SoS. The scope is not limited to the architectural part but also to detailed design. Consequently, the output is one or many systems forming the capability. It includes a significant technical component and a minor business component³⁵.

3.2 TP4 CEP Working Draft Perspective

The CEP Team's final objective is to propose a process that will enable the CE concept. Instead of opting for the development of an entirely unique CEP of its own, the project team was directed to consider for analysis (and eventually for adoption if proven appropriate) an existing perspective resulting from the efforts of an international team (TTCP JSA TP4). The perspective is known as the TP4 CEP Working Draft. This process is described in the document entitled "Overview of the Capability Engineering Process", produced in June 2003 and prepared for TTCP JSA TP4 by Mr Richard Schmidt of Systems Technology, Inc. [75]. This reference can be found in Annex A. An analysis quickly revealed that this process was based on a different understanding of the CE concept. Moreover, the implementation of this concept into a process did not meet the expectation following the initial works. This subsection presents the perspective of CEP from the TP4 CEP Working Draft description.

At the same time, CEP Team had chosen to consider the RDA CHENG NCEE for supporting the CEP. At this step, CEP Team noticed that the tools that were supposed to be tailored to support the process were not chosen necessarily for this purpose. These tools are enablers for CEP but can also impose some constraints on it.

Like most documents, the TP4 CEP Working Draft description defines a capability as composed of many systems (then as a SoS). However, the kind of SoS is not explicitly mentioned. Are these SoS virtual or dedicated? The answer can be deduced from references to long-term timeframe of capability. Since a dedicated SoS is created/evolved on a long-term basis, the TP4 CEP Working Draft description probably considers only a dedicated SoS. Consequently, the capability will be created/evolved over many years and not within a few weeks or months to counter a new and specific threat. Even if the process unambiguously associates a capability to a SoS, it does not define the size or granularity of this capability. This capability granularity problem will be discussed in the following section.

It is not clear from the above reference whether the TP4 CEP Working Draft purpose is to create, evolve or to maintain an operational capability. The document only mentions that an Initial Operational Capability (IOC) can evolve in an incremental

³⁵ DoD AF includes an important business part but, as it will be seen later, it is not as large as in the enterprise architecture.

way. However, it is impossible to know if this IOC is an evolution of an existing capability or if it has been created from scratch. This concept of incremental capability is a fundamental aspect of the evolutionary acquisition³⁶. This latest concept is present in the process.

Is the CEP role to create, evolve and/or maintain a capability?

Unlike traditional SysEng approaches that focus mainly on the system aspect, the TP4 CEP Working Draft description provided by Schmidt also includes important organizational and business details. In this document, the architecture description includes the organizational structure, the roles and responsibilities and the business processes associated with the organization in terms of systems and equipment. The TP4 CEP Working Draft is described as taking into account all enterprise layers³⁷ to find an integrated and globally optimal solution. This “enterprise” vision of a capability, instead of solely a technical vision, will be discussed further in the enterprise architecture of the following section.

In the second figure of Schmidt’s description of the TP4 CEP Working Draft, the life cycle for a capability is defined in three steps: operational analysis, CE and evolutionary acquisition. It ensues that the CE begins right after the Operational Analysis activity to ends up just before the system acquisition. It occurs concurrently to the concept definition phase of SysEng. Thus, it is not applied during detailed design, system integration, production and manufacturing, and others phases. The document is less precise about the phases of the life cycle considered. For instance, does this process take into account manufacturing or maintenance consideration?

The definition of the capability life cycle and the place of CEP within the phases of this life cycle have an impact on the input required by CEP and the output produced by CEP. Since one step must deliver its work to another step with deliverables, it is important to define these deliverables. Even though the activity preceding the CE is defined, the output of this activity and consequently the input of the CE is not known. However, the deliverable in output is clearly defined. Surprisingly, it is not a system or a capability but a description of a “vision” integrated architecture³⁸, documented into a transformation roadmap. This document contains information about the organisational evolution plan, the capability evolution objectives, the capability evolutionary roadmap, the force training and transition plan and the investment plan. It is not explicitly said to whom this document is intended.

What are the inputs and the outputs of CEP?
Who will use this information?

The process also generates an integrated architecture that could be used for the acquisition phase. However, this integrated architecture is not defined as a deliverable. Figure 10 clarifies the TP4 CEP Working Draft by locating its major phases and activities.

³⁶ See next subsection for more information on Evolutionary Acquisition

³⁷ See next subsection for more information on the layers of the Enterprise Architecture

³⁸ Architecture created with DoD AF is called integrated architecture.

<p>2.1 Define the “as-is” Integrated Architecture</p> <ul style="list-style-type: none"> - 2.1.1 Capture the “as-is” Operational Model - 2.1.2 Capture the “as-is” Physical Model - 2.1.3 Identify the Measures of Effectiveness - 2.1.4 Identify Areas of Opportunity for Improvement <p>2.2 Establish the Strategic Vision</p> <ul style="list-style-type: none"> - 2.2.1 Evaluate Availability of Technology - 2.2.2 Evaluate Doctrine and Tactic Evolution - 2.2.3 Evaluate Force Structure Evolution - 2.2.4 Document the Strategic Vision <p>2.3 Develop the “Vision” Integrated Architecture</p> <ul style="list-style-type: none"> - 2.3.1 Identify Candidate “Vision” Architecture Alternatives - 2.3.2 Evaluate Candidate Alternatives for Feasibility - 2.3.3 Select Alternative(s) for Concept Development 	<p>2.3 Develop the “Vision” Integrated Architecture (cont’d)</p> <ul style="list-style-type: none"> - 2.3.4 Develop Alternative(s) Operational Model - 2.3.5 Develop Alternative(s) Physical Model - 2.3.6 Evaluate Alternative(s) Architecture Cost/Effectiveness - 2.3.7 Select and Document the Preferred Alternative <p>2.4 Establish the Transformation Roadmap</p> <ul style="list-style-type: none"> - 2.4.1 Identify the Organizational (Force) Structure Evolution Plan - 2.4.2 Establish Capability Evolution Objectives - 2.4.3 Establish Evolutionary Acquisition Roadmap - 2.4.4 Establish the Force Training and Transition Plan - 2.4.5 Establish the Investment Plan
--	---

Figure 10: TP4 CEP Working Draft Activity Breakdown (from [58])

This “process” defines a small set of activities grouped into four major activities. There is no time constraint, triggered or triggering activities or schedule to apply the process (see section 4). The document does not define any formal or standard deliverables, aside from the transformation roadmap. Moreover, no mention of who will conduct these activities is given. There are neither any entrance criteria for each activity. Finally, the process remains silent on tools that could assist to apply the process. Should CEP complete these gaps?

What is the level of completeness of CEP in regard of What, When, How and With What should be reached?

Figure 11 shows an illustrated and interpreted version of the TP4 CEP Working Draft (activities, phases and internal information exchanges). It is based on deductions following meticulous readings of the process. It shows a possible time schedule of activities.

This process remains silent on the methodology that could be used for the SysEng part.

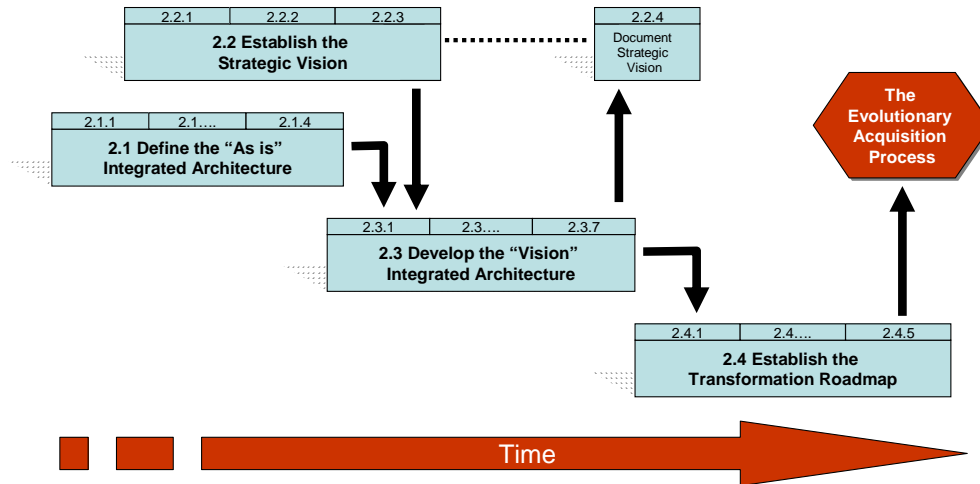


Figure 11: TP4 CEP Working Draft Activity Breakdown versus Time (from [58])

Another important concern is the level of refinement of CEP for each aspect of its completeness. For instance, an activity of CEP requires that we produce a deliverable called Analysis of Alternatives (AoA). The same activity could also require that we produce a Pugh Matrix. The latest is a format to present an AoA. Even if it could be restrictive, this level of specificity can guaranty interoperability at the deliverable level. Another example of the level of refinement is the quantity of deliverables produced during the process, not only for external use but also for internal information exchange. The TP4 CEP Working Draft states explicitly only one deliverable. On the other hand, others processes like the SLC of the Defence Finance and Accounting Service (DFAS) [24] states dozens of deliverables. Figure 12 shows an example of deliverables exchanges between activities of the TP4 CEP Working Draft. A process could be refined indefinitely but could not be worth the investment and could produce a too specific and restrictive (but optimal) solution.

What are the levels of refinement for CEP and to which levels of refinement CEP should be defined?

This process is independent to its context of application. Like other processes that will be presented later, it could be customized or tailored to better conform to the capability decision and development process of a specific organization. For instance, the SLC approach defines a set of activities producing a series of deliverables tailored to the decision making process and to the accounting services of the US DoD.

Should CEP be generic or tailored to its context of use?

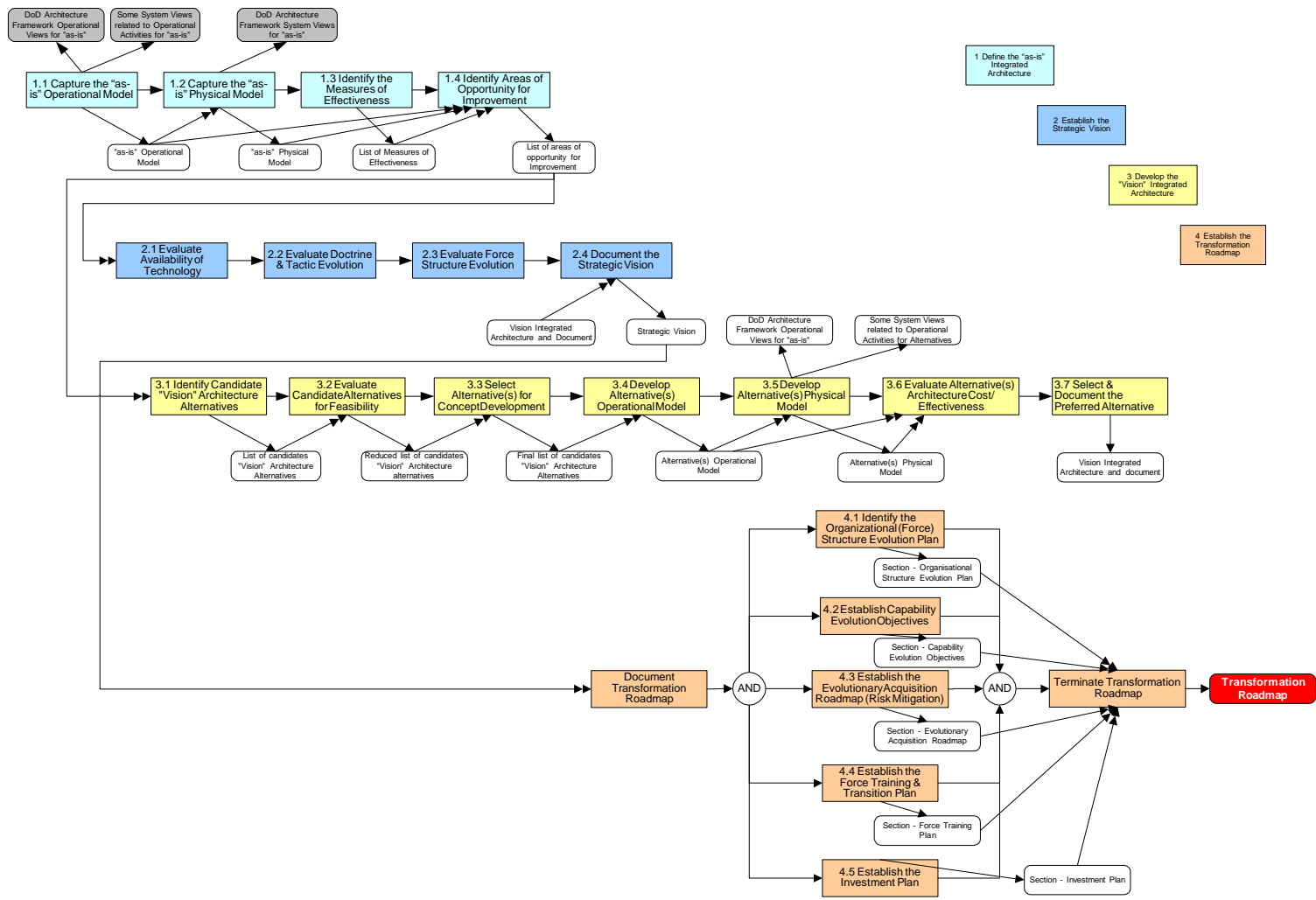


Figure 12: TP4 CEP Working Draft Interpretation

3.2.1 Discussion

The CEP described in the Schmidt paper on TP4 CEP Working Draft is a process that helps the creation and/or the updating and/or the maintenance of a capability over a long period of time. Unlike the first perspective of CEP, its output is a document, not a system or a capability. This document contains an AoA and the investment strategy that will be used by the decision maker and the acquisition community³⁹. Like most SysEng process, this CEP is independent of its context of application. The process described in the TP4 CEP Working Draft document takes into account both the technical, business and organizational aspects of a capability. Moreover, this process produces technical and organizational solutions. However, it is not possible to complete the perspective of the TP4 CEP Working Draft because many aspects are not clearly defined. For instance, this document is not clear whether or not CEP takes into account manufacturing and disposal considerations. Neither does this document define the size of a capability.

Even if the final objective is the same, this perspective differs considerably from the initial one. Since many valid perspectives (possibilities) of CEP can all reach the same final objective, it has been necessary to complete the possibilities of what CEP could be by performing further investigations.

3.3 Other Possible Perspectives

Previous investigations and works produced incomplete or incoherent views of the CE concept. For instance, it has been observed that two or more technologies were tackling at the same problem. It was also impossible to know the specific purpose (scope) of some technologies. Thus, further investigations were essential. Technologies, that are able to participate to the final CE objectives, have been reviewed to complete the two previously presented perspectives. This section will not present a single perspective but will consider all candidate solutions, possible scopes and process forms from all angles.

3.3.1 US DoD 5000 and Evolutionary Acquisition

The TP4 CEP Working Draft mentions the US DoD Directive 5000.1 [34] and US DoD Instruction 5000.2 [35][36][37]. These documents enable and standardize the concept of the Evolutionary Acquisition strategy. The US DoD 5000 Instruction and Directive documents specify the Evolutionary Acquisition and the Spiral Development Model as the most appropriate approaches for the acquisition in US DoD. The approach begins with a series of explorations to ensure the technology readiness and then proceed by doing Spiral Developments for a number of funding blocks. This approach has to adapt to a changing environment by rapidly acquiring and sustaining a supportable core capability and incrementally inserting new technologies or additional capability features, as they are available and mature. A basic

³⁹ The term acquisition means the activity following the capability definition phase like in the TP4 CEP Working Draft proposal.

capability is fielded with the intent to develop and field additional capabilities as requirements are refined. The role of this approach is to reduce the time a capability can be transferred to the field and used efficiently in the form of system (or SoS). These initiatives clearly share the same objective as CEP. However, at which level exactly the Evolutionary Acquisition and DoD 5000 are related to CEP is a study to complete.

The DoD 5000 do not define completely which phases of the life cycle it considers. However, they are well scoped in regard of the phases of the life cycle during which they are applied. They apply from concept refinement to disposal (concept refinement, technology development, system development and demonstration, production and deployment, operations support - disposal). The phases before concept refinement are done by the Joint Capability Integration and Development System (JCIDS) of the Chairman of the Joint Chiefs of Staff Instructions (CJCSI) 3170 [19]. The DoD 5000 receive as input a document called Initial Capabilities Document (ICD) in which the capabilities and material solutions are roughly defined.

The DoD 5000 are not designed to produce a complete capability. Even if it takes into account many components of a capability like Doctrine, Organizations, Training, Materiel, Leadership, Personnel and Facilities (DOTMLPF), it only proposes a material solution.

Should CEP consider and propose a solution for all these aspects (such as DOTMLPF or PRICIE) ⁴⁰ or be more selective like the 5000 acquisition strategies?

Like the TP4 CEP Working Draft, the DoD 5000.1 participates in defining Capability Roadmaps, Capability Assessments, Investment Strategies and Integrated Architecture. The purpose of these documents is to integrate the requirements with the acquisition, i.e. integrate CJCSI 3170 requirement process with the DoD 5000 acquisition process.

The bridge between the requirement of a capability (regulated by CJCSI 3170 requirement process in the US) and the acquisition of a capability (regulated by the DoD 5000 directive and instruction in the US) is essential to the successful creation and improvement of this capability. This concept is called Capability-Based Methodology. Such bridge is possible by using an integrated architecture. DoD has developed the DoD AF framework to come with such an integrated architecture. However, other similar frameworks⁴¹ from the Enterprise Architecture community are also good candidates (similar or complementary) that could be used to reach similar objectives.

⁴⁰ PRICIE (Personnel, R&D/Ops Research, Infrastructure & Organization, Concepts, Doctrine & Collective Training, IT Infrastructure, Equipment, Supplies and Services) is the Canadian version of DOTMLPF.

⁴¹ See next Subsection.

3.3.2 Enterprise Architecture

Enterprise Architecture [61] and its engineering should be considered in the elaboration of CEP. For instance, the TP4 CEP Working Draft was defined to be the combination of the Enterprise Architecture Concepts and the System Acquisition Process. The purpose of an enterprise architecture “is to support the company's corporate vision and strategy. Therefore the company’s vision and strategy must be allowed to support and define all elements and aspects of the enterprise architecture. If properly defined and managed, an enterprise architecture will serve to control and contain costs throughout the lifecycle of the project.”⁴². This cost-control and corporate vision are closely related to the objectives of CEP and the means used by the TP4 CEP Working Draft to reach its objectives.

An enterprise architecture is always composed of a number of sub-architectures. Even if there is no common agreement on what should be included in Enterprise Architecture, it always contains a business and a more technical portion, as illustrated in Figure 13.

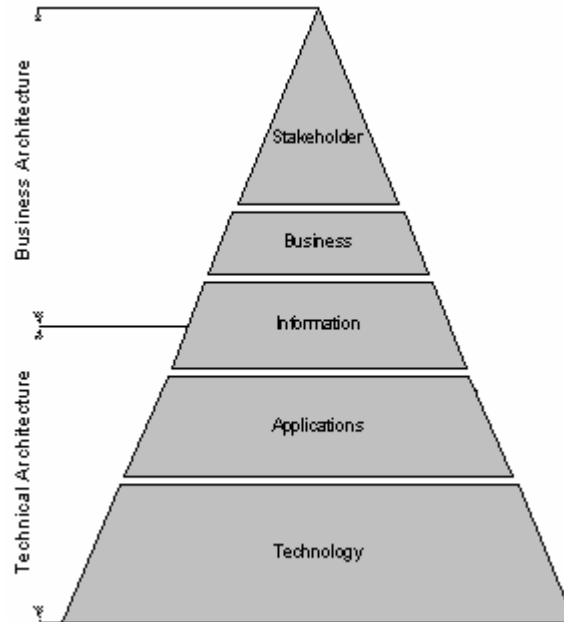


Figure 13: Enterprise Architecture Layers (from [54])

The business level describes the business strategies, the processes, and the functional requirements that are needed to support the business goals and objectives. It can include how the organisation works, both the administration and the operational portion of the enterprise. The technical part is more related to technologies required to support the enterprise changes (used or

⁴² JP Rushing Consulting. 2003. Available at http://www.jprushing.com/ECM/Enterprise_Architecture.asp

produced). In the CapDEM project, the capability improvement or development should require business and technical modifications. Until now, most solutions related to CEP dealt mainly with the technical layer of the enterprise. The integrated architecture in DoD AF is an exception since its operational models include a business portion.

Should CEP deal with the technical layer only, the technical and a part of the business layer like in an integrated architecture or go further by including both technical and most business aspects such as organization operations like in the TP4 CEP Working Draft?

If CEP tackles all the life cycle, the process would cover the technical aspect entirely in its smallest detail. On the other hand where CEP scope is restricted to some portion of the life cycle like in the TP4 CEP Working Draft (it stops at the transformation roadmap), it is not clear, for both technical and business layers, how broad and which level of detail should be covered. The cost associated to plan a detailed design would be very high and would contradict the concept of the planning in which a small portion of total resources is spent in order to plan the order portion. However, the necessity to drill down the design of some parts/systems of the technical or business level can be justified by reducing the risks and the unknowns of the project. This way, managers could take the decision on solid basis even if the design of the various components/systems is not entirely completed.

Which level of detail and of broadness should be reached for the business and the technical level?

The Enterprise Architecture is commonly used by various enterprises in the world. The general concept is well understood but each enterprise has adapted it to its own individual needs. The Open Group's Architecture Framework (TOGAF) [79], the DoD AF, the US Federal Enterprise Architecture Framework (FEAF) [17], the Zachmann Framework [88] for Enterprise Architecture, and the US Treasury Enterprise Architecture Framework (TEAF) [25] are all examples of enterprise architectures. Many of them have a strong acceptance in the civil domain.

3.3.3 Transformation Roadmap

The deliverable of the TP4 CEP Working Draft is a Transformation roadmap. This document contains information about the organisational evolution plan, the capability evolution objectives, the capability evolutionary roadmap, the force training and transition plan and the investment plan. This information is intended to help the decision-making and the acquisition process. The US DoD uses a similar transformation roadmap. All US DoD Services must produce every year, in accordance with the Defence Planning Guidance [65], a roadmap [18][82][83] that explains how they will build the capabilities necessary for executing the six critical operational goals identified in the quadrennial Defence Review Report [33]. These capabilities (26 for two of

the three documents) are called transformational capabilities. However, it seems that the capabilities described in these documents are at a higher level (or bigger) than the capabilities described in TP4 CEP Working Draft.

Since a capability can be defined at various level of granularity, which level is optimal to reach the objectives of CEP?

An extension of this question is the following:

Should CEP cover a single or many capability(ies)?

If a capability can be decomposed into many smaller capabilities, this question is meaningless.

3.3.4 **Large Scale System Engineering Process (LSSEP)**

The RDA CHENG group is actually working on the LSSEP [31]. “The term LSSEP is meant to define the SysEng processes for Integration and Interoperability (I&I) of FoS or SoS”. Like many other solutions, LSSEP final objective intersects considerably with those of CEP. Like the TP4 CEP Working Draft, it defines a strategic capability plan and a capability evolution document. The following sentences resume the role of LSSEP in the acquisition:

“The BCAPP (Battleforce Capability Assessment and Programming Process) and the Acquisition of Major and Non-major Systems Process do not run in synchronization. The BCAPP is budget driven and runs on the budget cycle. The Acquisition process can be lengthy and is milestone driven. As FoS and SoS are formed, either from the BCAPP Capability Evolution Document (CED) or other initiatives, the programs that are grouped together to achieve mission capabilities will be in different stages of their life cycle, be managed by different program managers, be grouped in different PEO’s (Program Executive Office), or supported by different SYSCOMS. Consequently, the SysEng IPT becomes the critical forum for identifying and resolving I&I issues. The key LSSEP product for this effort is the Systems Performance Document (SPD).” [31]

The LSSEP is composed of a sequence of activities, based on IEEE 1220, producing a set of documents: an Interim Capstone Requirements Document (ICRD) containing the operational capability description and the Key Performance Parameters (KPPs), an Integrated Strategic Capability Plan (ISCP), an Integrated Sponsor Program Proposal (ISPP) document, a Capability Evolution Document (CED). The content of most of these documents is similar to the deliverable of the TP4 CEP Working Draft. The ICRD preceding the others document, however, could be used in input to the TP4 CEP Working Draft. If LSSEP were translated to the Canadian context, CEP would extend to the requirements analysis phase.

The deliverables of LSSEP are more numerous and more adapted to the decision making process and business rules of the US. On the other hand, a

process like the TP4 CEP Working Draft can deliver organization independent documents. CEP will have to specify deliverables independent of the utilization context or deliverables tailored to the (Canadian) organization. This choice will refer as its level of adaptability to the organization.

Figure 14 is taken from a LSSEP presentation. It is clear that they define capability on SoS and FoS.

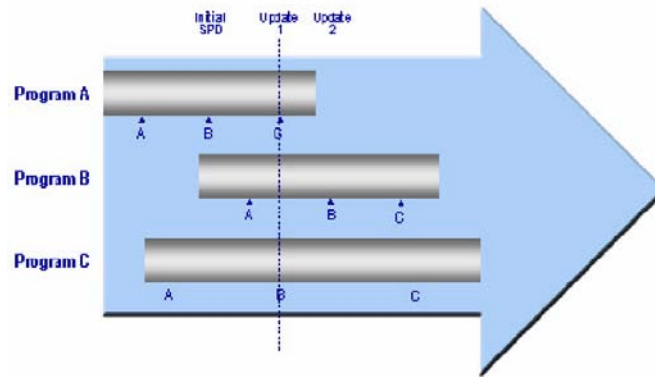


Figure 14: LSSEP Presentation (from [73])

Like the CBP, Figure 14 shows the need to manage and synchronize various programs (systems) to sustain or improve a capability.

3.3.5 Discussion

Many industrial and military technologies and approaches presented in this section may help in setting up and improving military capabilities for the Canadian Forces. The possibilities of scope are larger than ever, with solutions extending over the whole life cycle and extending over both technical to business levels of the enterprise. Some investigations show that the process can be tailored closely to the decision making process, contrary to what has been encountered in the previous perspectives.

3.4 CEP Team Understanding

The previous sections have presented existing candidate solutions, scopes and process forms. They are fundamental to define or evaluate any solution, called CEP in this project, to improve acquisition, maintenance and/or update of a capability. This section summarises these candidate solutions, scopes and process forms to create an integrated version of all presented perspectives.

3.4.1 Candidate Solutions

As a recall, the main goal in CapDEM is to develop a CEP that will help at improving decision-making for strategic investment. This CEP is still in its infancy. Work must be done to identify the already working technologies that could be introduced within the CEP. Additional efforts will have to be done in order to identify, define, and develop all missing technologies that will

complete the CEP. Figure 15 illustrates some technologies that are already used.

Which existing candidates solution should be taken into account and included in CEP?

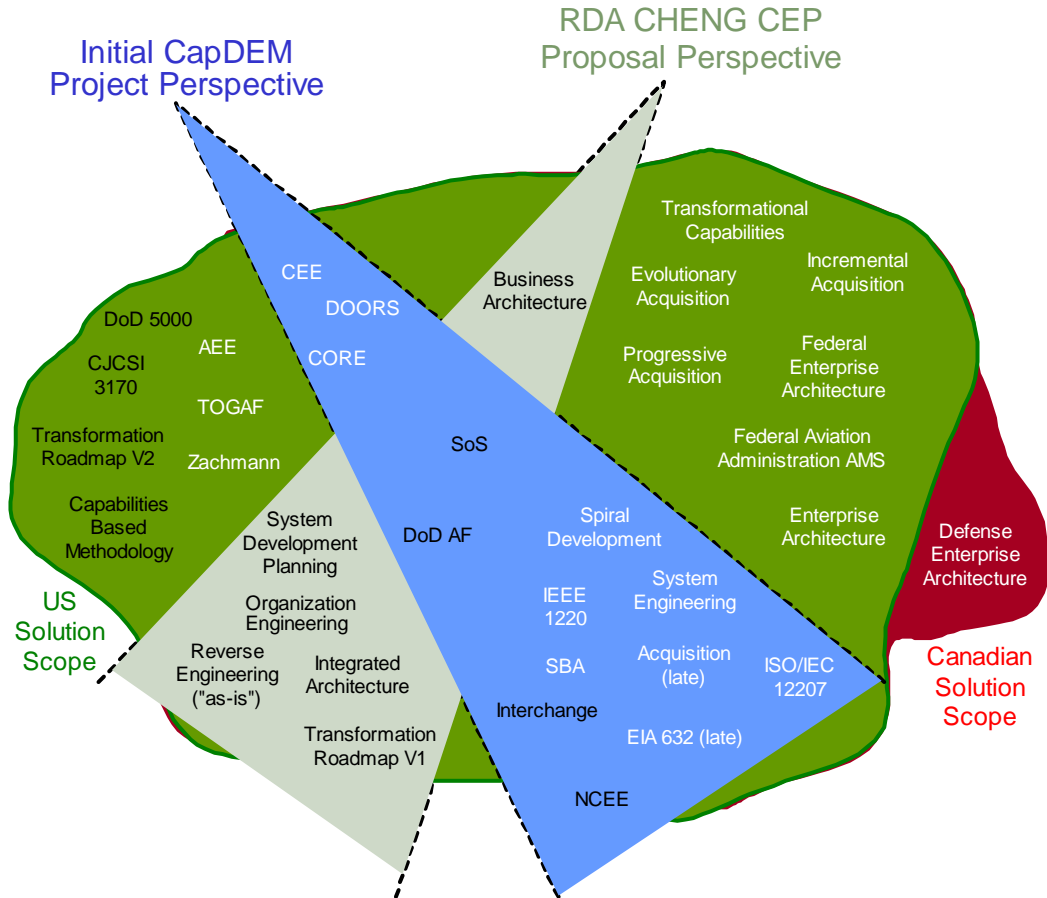


Figure 15: Candidate Solutions from Different Perspectives

As shown in this figure (and largely discussed in earlier sections), there are many potential industrial and military solutions. These technologies provide the necessary scientific rigor to address problematic such as military acquisition (Evolutionary Acquisition, US DoD 5000 documents, CJCSI 3170...), software engineering (RUP, UML...), SysEng (IEEE 1220, ISO/IEC 12207, Spiral Development...), architecture description (DoD AF, TOGAF, Zachmann, Enterprise Architecture...), and others.

Yet, there exist no standard or framework that allows system engineers to completely address this problematic. Works have been started to bring standard SysEng to a point where complexity, which emerges from collaboration between autonomous systems (made of people, processes, and technologies), becomes more deterministic, predictable, and thus manageable.

The starting point to build/develop/create the CEP is the actual industry and military solutions or technologies that are illustrated in Figure 15. Some characteristics of this set of technologies relevant to CEP Team work in the CapDEM project are the following:

- They were mainly conceived in US.
- There are overlaps and gaps between them.
- As they are the result of many different efforts, these solutions are not integrated.
- In terms of levels, their scope varies but is often at an enterprise level.
- They are difficult to compare and thus, to evaluate.

Many questions, not easy to answer at this moment in CapDEM project, can be raised at this moment:

- Which technologies (listed in Figure 15) should be used within the CEP and in what order?
- Considering the needs for the CEP, how should these technologies be used and how should they be used together, are they complementary, are they compatible?
- Which technologies are missing to complete the CEP?
- Are CASE tools ready to support these technologies (and thus the CEP)?
- If not, does a strategy need to be established (for using these technologies and tools) that will follow the evolution of CASE tools functionalities?

CASE tools will help synchronize the use of all technologies within the CEP. It is probable that many complementary CASE tools (supporting the concurrent use of many chosen technologies) will be involved within the CEP. These tools will have to be able to be used concurrently to give the CEP all its efficiency and effectiveness.

The complexity emerging from such complex projects will involve many important factors (human, technological, procedural...) and links between them. These will have to be considered within the CEP and the chosen technologies and tools will have to ease their consideration and their understanding by all relevant stakeholders. For example, the modification of one determinant aspect of a studied architecture (called a factor) must be reflected at all relevant other locations in the architecture and at all relevant stakeholder levels to insure the needed coherence and synchronization in the project. The CEP and its technologies will have to provide all functionalities

that will support the propagation of all relevant information at all relevant locations. In addition to traceability, it will also provide means to insure coherence and synchronization.

3.4.2 CE Scope

As mentioned at the beginning of this section, CE can be interpreted (or defined) in many ways. Its scope contains many possible interpretations of CEP. This scope is defined into three main categories: (i) capability characteristics, (ii) characteristics to consider or having an impact, and (iii) applications to obtain a future capability.

CE can be conceived from a selection of various possibilities at each category of the scope. The two following examples give possible ways that CEP could be applied:

- The CE tackles an evolving medium-size FoS-based capability in a few months for a specific mission. Some of these systems are owned by allies. It identifies requirements, explores concepts, develops, and integrates all the systems. It takes into account training and maintenance considerations. It does not consider organizational constraints and does not change any business rules (doctrine, organization...).
- Another CE context of application is to create, over a long period of time (5 years), a dedicated SoS. All constituents of a capability are considered as well as all the enterprise levels. However, the process only proposes a material solution with a minor modification into the organization if required. The process creates a transformation roadmap that is used as a guide and input for the acquisition activity. It is used as a starting point for detailed configuration item design and other remaining phases.

These two examples imply different constraints and issues. Consequently, it is not obvious that the CE could support the creation/evolution of these two different capabilities.

Ideally, the CE could cover the whole scope. However, a realistic approach will be to select only a part of the possible scope of CE.

Figure 16 presents the characteristics or factors that can influence the scope and the specific objectives of CEP. Depending of the size of a capability, which constituents of a capability are taken into account and the timeframe allowed to upgrade or develop a capability, the CE specific objectives and approach will not be the same. The scope can be extracted from the following categories:

- **Capability Characteristics:** What is included in a capability? What are its characteristics? The following points give some characteristics of a capability with many examples for each of them.

Size: Capability Area, Transformational Capabilities, Medium-Size Capability, Small-Size Capability...

System Arrangement: Single System, SoS, FoS...

Constituent: People, Doctrine, Techniques, Tactic and Procedures (TTPs), Material, Organization, Support, Training, or DOTMLPF or PRICIE...

Enterprise Level: Technical, Business, both (fully or partially)...

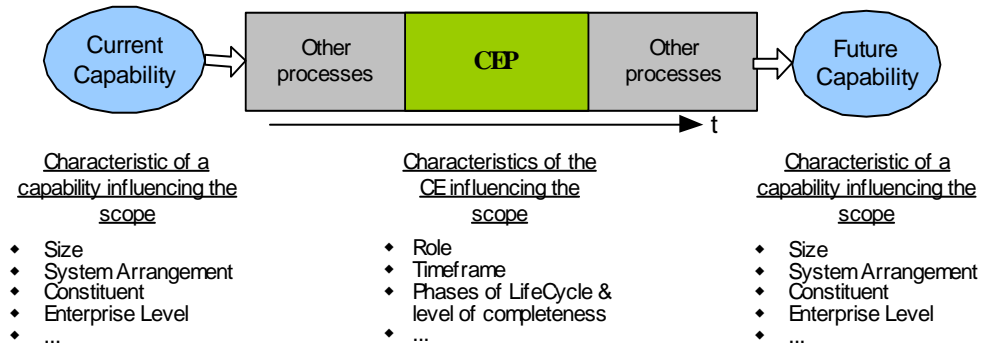


Figure 16: *The Characteristics of a Current Capability, the Nature of CEP and the Characteristics of a Future Capability Influencing the Scope of the CE*

- **Characteristics to consider or having an impact:** What does the CEP consider to find the best solution? What are the characteristics having an impact of the CE? The CE can take into account only some characteristics of the current capability and some portion of the life cycle of the future capability. Examples are given for each aspect.

Phases of the life cycle / Level of completeness: Concept Definition, Detailed Configuration Item Design, System Integration, Production & Manufacturing, Training, Deployment, Operation, Maintenance, Refinement and Retirement...

Constituents, System Arrangement and Enterprise Level(s): See first category for examples. CE can decide to take into account these characteristics partially to optimize its resources.

Size: See first category for example. Even of this characteristic has an impact on the CE, it is out of control of the CE.

- **Applications to obtain a future capability:** The application category contains all points relevant to its application and the effect of CE on the future capability.

Role/Task: Create, Maintain, Improve or Evolve (Self-Evolution, Joint Evolution and Emergent Evolution)

Timeframe: Short-Term (Days), Mid-Term (Months), Long-Term (Years)

Phases of the life cycle / Level of completeness: Concept Definition, Detailed Configuration Item Design, System Integration,

Production and Manufacturing... Each one completely or at various levels of completeness.

Constituents, Supporting System(s) and Enterprise Levels: See first category for examples. CE can decide to propose a capability in regard of some portions of its characteristics.

Size: See first category

3.4.3 Process

A concept itself is useless unless it can be applied. The process is a means by which the concept of CE is concretized. Even if the concept is well defined and scoped, the process can take many forms. The four next categories give an idea of the possible forms of CEP:

- **Methodology:** Spiral, Iterative, Incremental, Waterfall, Custom, None (Independent of the Methodology), ...
- **Level of refinement:** AoA vs Pugh Matrix, 1 vs 20 deliverables, ...
- **Completeness:** What, When, Who (roles), With What (tools), Entrance Criteria, Exit Criteria, Goal and Reference(s) for each activity, Input and Output, ...
- **Level of adaptability to the organization:** activities or deliverables, generic or tailored to an organization.

Unlike the scope, all the dimensions of the process can be easily implemented in an incremental way. For instance, the process can refine its deliverables (in number or in specificity) gradually at each evolution without changing previously works.

The CapDEM project initially hypothesized that the solution would be a process. However, in the case a global process could not be found, it will be necessary to create a process for each application. A process generator such as a framework, guidelines or a meta-process could be the solution. It is not possible to commit to the right solution without knowing better the capability development context and its requirements.

3.4.4 Discussion

This section presented many possible perspectives of CEP. Even if they are all valid versions of CEP, it is not possible to support and include all these technologies and scope for two reasons. Firstly, it is difficult to choose within the scope and technologies until specific requirements of the Canadian capability development community and actual acquisition problems are well identified. Secondly, the problem space of the CE is too large. An initial solution will tackle only a portion of the problem. The same argument is also valid for the process. A complete process dictating everything of how to create, update or maintain a capability would be ideal. However, a progressive development approach for the process is more appropriate.

4. TP4 CEP Working Draft: A Theoretical Assessment

This section presents the analysis of the TP4 CEP Working Draft as described to TTCP JSA TP4 in the document entitled “Overview of the Capability Engineering Process” produced in June 2003 [75] and found in Annexe A. As mentioned in Section 2.2, although this document is an overview, it was the best source of information the CEP Team could find to proceed with the analysis.

The analysis is based on two independent theoretical efforts: an internal DRDC effort and an industrial one. The DRDC CEP Team members performed the first one during a two-days workshop held in Valcartier. Before this workshop, the CEP Team members read several documents about acquisition and CBP. Some were directly referred in the above-mentioned TP4 CEP Working Draft document. The workshop’s main objective was to achieve a consensus about strengths and limitations of the proposed process. Mr Jocelyn Leclerc, a consultant having experience in different contexts, conducted the other effort in order to provide an industrial point of view. The consultant delivered a document entitled: ChEng Capability Engineering Process Assessment Report [58] referred as the CGI Analysis report in the following. After conducting these two efforts, a meeting was organised with the author of the TP4 CEP Working Draft document (Schmidt) in order to confirm and get additional information.

The following sections present the consolidated results of these efforts. The strengths and limitations are described. The recent meeting with Schmidt modified or reinforced our understanding of some strengths and limitations. In such cases, clarifications are reported in a box. This chapter concludes with comments about the TP4 CEP Working Draft according to our current understanding.

4.1 Strengths

The strengths presented in this section are related to the process approach, references, deliverable, metrics and modeling. They describe rather high-level observations.

4.1.1 Standard Approach

The process follows a standard and commonsense approach similar to Enterprise Architecture processes and TOGAF. It starts with the “as-is” definition, defines a long-term vision, assesses different options, chooses the best one in order to achieve the vision with respect to constraints and define required investments. Finally, the selected solution can be divided into incremental steps.

The process considers some elements of the DOTMLPF: Doctrine, Organisation, and Material. In addition, it takes into account tactics elements. The process is generic and described very high-level activities allowing adaptation to particular contexts.

The process is capable of addressing DOTMPF elements. The L –

Leadership and Education piece is not completely addressed. The process is the combination of Enterprise Architecture concepts and the System Acquisition Process. Within each domain, the SysEng process provides the basis for decomposing the complexity of the problem, and to enable assessments, analysis, and trade-offs among alternative solutions.

4.1.2 Known References

The process is the combination of DoD Acquisition Policies and Key Enterprise Architecture concepts. These were combined by the author to produce a more comprehensive framework for developing and assessing “Architectures” to support Enterprise Investment Decisions. The process refers to different well-known standards and documents: US DoD Directive 5000.1 and DoD Instruction 5000.2. The IEEE 1220 is not explicitly mentioned but some activities are inspired from it. The process proposes some deliverables following DoD AF format.

4.1.3 Transformation Roadmap Definition

The content of the final deliverable is well defined. Each activity of the Section 2.4 [75], Establish the Transformation Roadmap, describes a specific section of the final deliverable.

4.1.4 Metrics Consideration

The process suggests the identification of measures of effectiveness to evaluate performance, efficiency, effectiveness and resource utilization.

4.1.5 Model-Driven

The process requires the development of operational and physical models. Our assumption in the context of the process was that models could be simulated. This fact means that models provide a basis for assessment and engineering analysis and to enable trade-offs among alternative solutions.

The author confirmed that his definition of a view is a static representation while a model is a dynamic one that is executable.

4.2 Limitations

The limitations presented in this subsection concern process scope, activities, figures and definitions. In opposition to the strength presented in Subsection 4.1, they are more specific observations.

4.2.1 US Specificity

This process has been developed to address the US acquisition problem space, specifically from a US Navy perspective. It is not necessarily applicable to the specificities of DND/CF’s acquisition process. Some work is

required to better understand unique and common elements of the US approach.

4.2.2 Overall Schematic View

An overall schematic view is missing in order to visualize the sequence and the parallelism of the activities. This would facilitate the understanding of the existing schemas and provide an overview of all activities involved in the process.

4.2.3 Scope and Intention

The process description is more at the management level than at the SysEng level. In addition, the capability concept is not sufficiently addressed.

Schmidt explained that the TP4 CEP Working Draft addresses mainly the capability management level as shown in **Figure 17**. Schmidt suggests building the CEP from the IEEE 1220. It can be applied at all levels of Organization, for mid to long term planning, and across Service, Joint Service and Allied/Coalition endeavours. For that reason, it was discussed as something to be explored by the TTCP JSA TP4 Committee.

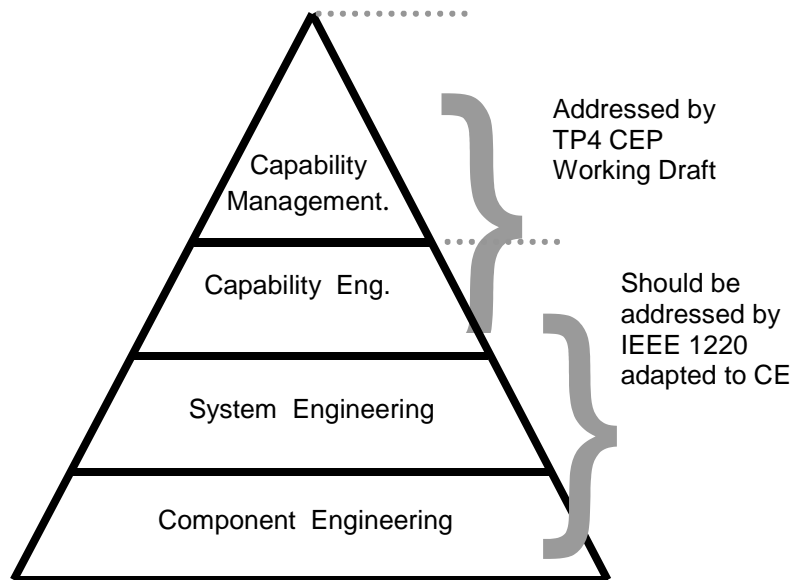


Figure 17: Process Scope

4.2.4 Boundary and Context

The process is missing an initial activity to define the boundary and context of the capability. Best practices suggest starting a system development by identifying its boundaries and understand its environment.

4.2.5 Activity Description

The level of details of activity descriptions varies a lot. For example, the activities in Section 2.4 [75] describe the content of each section of the deliverable “Transformation Roadmap” while others mention only the type or title of the output without any details of the content. For instance, each activity description could include the following information:

- Goal and objectives: What are the goal and the objectives? How deep does CEP Team have to go to achieve the objectives?
- When: When could this activity be performed? Can it be done concurrently to another?
- Input: Which information is needed to achieve the activity? What is the format of each input?
- Output: What are the deliverables to produce, their format? Are template descriptions and examples of the output available?
- How: How is it executed? What tools can help performing the activity? How to share information among the people involved in this activity?
- Who: Who is involved in this activity? What are the roles and responsibilities of the participants? What kind of expertise and knowledge is required for each role?

4.2.6 Requirements Management

The requirements and user expectations management is partially addressed. According to SysEng guidelines, an iterative process of validation is preferred.

The requirements are handled at the previous stage: Operations Analysis. This supplies the set of requirements necessary to start the CEP. Those requirements address the material part of DOTMLPF.

4.2.7 CEP Figure

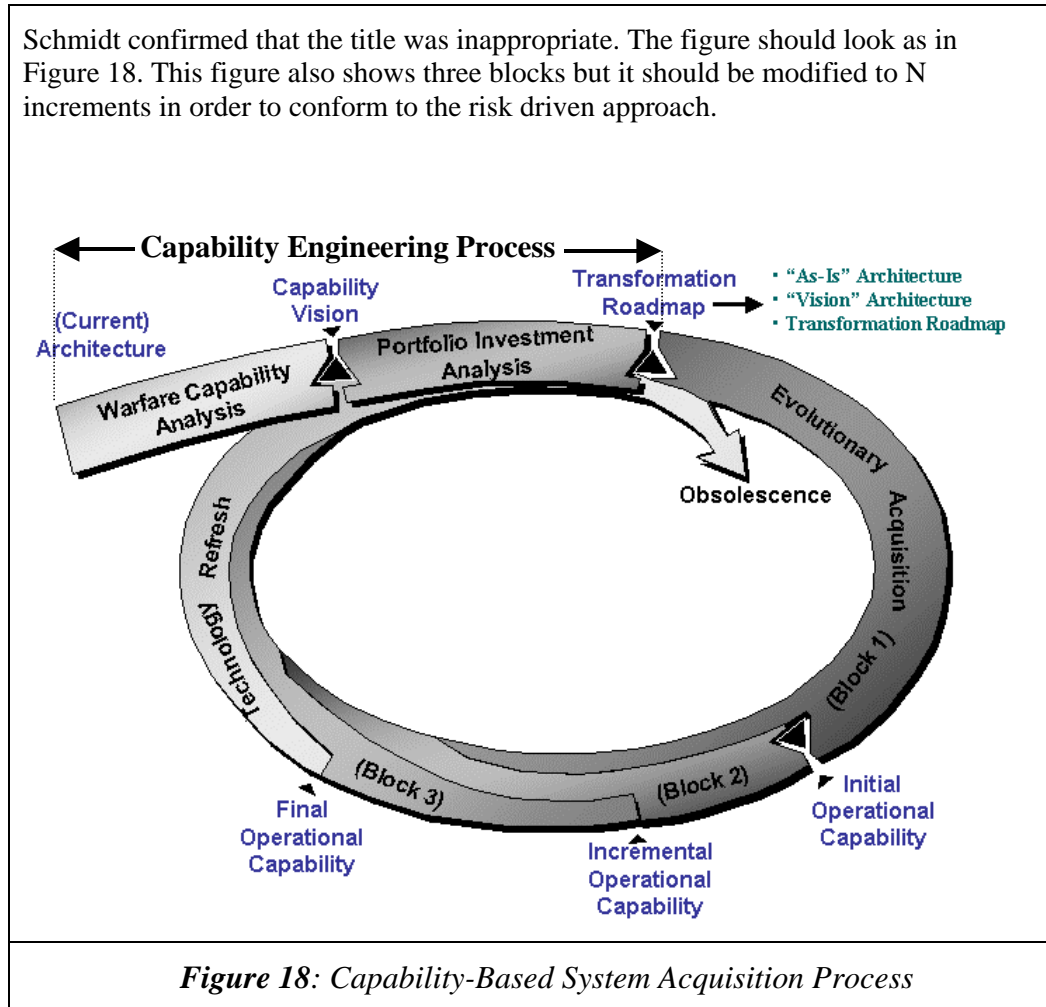
The title of the first figure in [75] is misleading. The figure shows the Capability-based System acquisition process while the title “Capability Engineering Process” refers only to the two first phases in the Capability-based System acquisition process.

Based on the evolutionary acquisition process, the increments should be risk driven. The number and scope of delivery increments may vary according to anticipated risks. In order to emphasize this fact to the reader, the first figure of the document should show an undetermined number of increments instead of three.

Some of the important concepts introduced in Figure 1 of the document do not appear in the Process description provided in the document (see Annexe

A). These concepts are: “Warfare Capability Analysis”, “Capability Vision” and “Portfolio Investment Analysis”.

Schmidt confirmed that the title was inappropriate. The figure should look as in Figure 18. This figure also shows three blocks but it should be modified to N increments in order to conform to the risk driven approach.



4.2.8 Glossary References and Definition

A glossary, a list of references and a definition sections are missing. Although the terms are known, they have different meaning for different authors. To provide a common understanding, important concepts need to be defined e.g. model, view, business process, functional model, operational view, capabilities objectives, strategic vision, value-added.

4.3 Qualitative assessment

This subsection presents a qualitative assessment of the TP4 CEP Working Draft in Table 1. It summarises well the current thoughts of the CEP Team about this document. The criteria used were proposed in the CGI Analysis report. For each of the criterion, an appreciation is expressed through a short comment, according to the understanding of the process and the context when the assessment was conducted.

Table 1: Qualitative Assessment

QUALITY	DESCRIPTION	COMMENTS
Relevance	This criterion measures Process' applicability to DND/CF specific context.	A DND/CF problematic understanding is missing to properly address this criterion.
Compliance to Standards	This criterion measures Process' adherence to Military Standards in the areas of SysEng, Enterprise Architecture and Military Acquisition.	The process refers to 5000.1, 5000.2 and suggests DoD AF deliverables.
Functional Quality	This criterion measures Process' quality with regard to the richness and completeness of the functions it offers to address and solve the process at hand (i.e. Capability-Based Military Acquisition).	The following limitations were identified: Activity Descriptions, Requirements Management, Boundary and Context.
Technical Quality	This criterion measures Process' quality with regard to its technical elements such as its toolset, technical infrastructure, etc.	As mentioned in the Activity Description limitation, there are no references to toolsets or technical infrastructures.
Effectiveness	This criterion measures Process' ability to meet predetermined objectives.	The process has not been completely applied yet. The JIIFC application is still in progress.
Efficiency	This criterion measures Process' ability to minimize resource usage while meeting predetermined objectives.	As identified in Section 4.2, activity descriptions do not specify who is performing the activity.
Usability	This criterion measures Process' learning curve, ease of implementation, and ease of use.	The following limitations were identified: Overall Schematic View, Activity Description and Glossary, References and Definition.
Impact	This criterion measures Process' impacts on current DND/CF Organization, methods, procedures and tools.	A DND/CF problematic understanding is missing to properly address this criterion.
Maturity	This criterion measures Process' level of progress currently achieved with regard to demonstrated capability in the area of Military Acquisition.	The process is a draft document and is under definition.
Continuity	This criterion measures the long-term commitment of the sponsoring organizations with regard to support and evolution of the process.	It is too early to assess this criterion.
Cost	This criterion measures Process' direct and indirect resources that are required for its acquisition, implementation and use.	A DND/CF problematic understanding is missing to properly address this criterion. In addition, as mentioned in the Activity Description limitation, there is no indication about who is conducting the activities.

4.4 Applicability

The TP4 CEP Working Draft in its current overview version is not applicable by itself. Many elements, steps and outputs are not clear enough to be useable. The user has room for a lot of interpretation, which could lead to different implementations for the same kind of problem. The targeted process should be self-understanding and self-applicable to avoid such interpretations. The process should allow to re-use models and data enabling leveraging between capabilities.

Considering the limitations, the Transformation Roadmap may not provide all adequate information to support strategic investment decisions for DND/CF capability implementation.

5. TP4 CEP Working Draft: A Practical Assessment through JIIFC Case Study

The JIIFC case study aimed at learning from the TP4 CEP Working Draft, its CEE, and the associated body of knowledge. This case study applied the TP4 CEP Working Draft based on Schmidt's documentation and used the CEE toolset to support JIIFC concept definition activities. Lessons-learned are being captured as the activities in JIIFC continue. From August to November 2003, CEP Team focused its activities on context/boundary definition, requirements analysis, and modelling a subset of the current environment. In this section a preliminary assessment of the TP4 CEP Working Draft based on these activities is presented. Table 2 summarises which activities of the TP4 CEP Working Draft were partially or totally addressed within this effort.

Table 2: TP4 CEP Working Draft Activities Addressed with the JIIFC Case Study (2003)

TP4 CEP Working Draft Activities	Performed for JIIFC (2003)
1 Define the "as-is" Integrated Architecture	
1.1 Capture the "as-is" Operational Model	Total
1.2 Capture the "as-is" Physical Model	Total
1.3 Identify the Measures of Effectiveness	Partial
1.4 Identify Areas of Opportunity for Improvement	Partial
2 Establish the Strategic Vision	
2.1 Evaluate Availability of Technology	Partial
2.2 Evaluate Doctrine & Tactic Evolution	Partial
2.3 Evaluate Force Structure Evolution	Partial
2.4 Document the Strategic Vision	N/A
3 Develop the "Vision" Integrated Architecture	
3.1 Identify Candidate "Vision" Architecture Alternatives	Partial
3.2 Evaluate Candidate Alternatives for Feasibility	Partial
3.3 Select Alternative(s) for Concept Development	Partial
4 Establish the Transformation Roadmap	
4.1 Identify the Organizational (Force) Structure Evolution Plan	N/A
4.2 Establish Capability Evolution Objectives	N/A

4.3 Establish The Evolutionary Acquisition Roadmap (Risk Mitigation)	N/A
4.4 Establish the Force Training & Transition Plan	N/A
4.5 Establish the Investment Plan	N/A

As a CapDEM activity, the scope of this case study focuses mainly on the application and analysis of the TP4 CEP Working Draft and the associated toolset. Nonetheless, the CEP Team works together with the JIIFC project team to ensure the work being carried out meets the objectives and requirements of both the CapDEM and the JIIFC projects.

5.1 The JIIFC Project

The JIIFC project supports the departmental vision to provide decision-makers with the timely and relevant fused information needed to command and control CF operations whenever and wherever they take place around the world. The mission of JIIFC is to deliver an integrated situation awareness capability that supports all levels of command. Detail description of the project can be found in the JIIFC Concept of Operations (ConOps) [50] and the Statement of Operational Requirements (SOR) [51].

Currently, JIIFC is in its definition phase to further develop the concept of a joint fusion capability to support strategic level command and control. The first versions of ConOps and SOR have been developed before CapDEM's participation. These two documents serve as valuable input to the JIIFC concept definition process. The main expected outputs from the JIIFC concept definition process are two well defined ConOps and SOR documents to support acquisition. The definition phase will be facilitated by Modelling and Simulation (M&S) coupled with requirements traceability.

5.2 The JIIFC Concept Definition Process

The JIIFC concept definition process is adapted from the Schmidt description of the TP4 CEP Working Draft, the IEEE 1220 [44], and the IEEE 1362 [45]. The TP4 CEP Working Draft provides a high level description of the planning and engineering activities, while the two IEEE publications serve as guidelines for detail activities and contents of outputs throughout the process. Following accepted standards ensures that the concept definition process (from here on referred to as the JIIFC Process) does not deviate from mature engineering methodology.

Figure 19 is an overview of the JIIFC Process presented as an Enhanced Functional Flow Block Diagram (EFFBD) produced using CORE. The notations of EFFBD are very simple: boxes are activities, incoming arrows are inputs, and outgoing arrows are outputs. The circles labelled LP represent Loop-backs, denoting the iterative nature of the process.

Although the process presented in the diagram is a linear process, some activities are being carried out in parallel, or overlapping one onto the other. However, the degree of parallelism and overlapping depend on the availability of information. For instance, the ConOps and SOR already captured much information needed to support both

operational analysis and modeling of “as-is” environment, these two steps were being carried out in parallel. The following paragraphs describe the process activities as depicted in the EFFBD in the following paragraphs.

5.2.1 Operational Analysis as a Trigger

Operational analysis is the effort to identify high-value systems concepts and their enabling technologies in a way that is objective, traceable and robust [49]. Typically, operational analysis is a strategic enterprise-level activity that leads to the identification of multiple new capabilities. The collection of related capabilities is usually described as a Capstone ConOps, which becomes the guidance document for integrated lower level capabilities. For instance, a C4ISR Operations Analysis would lead to a C4ISR Capstone ConOps, which would identify mission need, operational concepts and relationships for JIIFC in the context of the Capstone ConOps. Within the C4ISR Campaign Plan [6], JIIFC represents a single capability to provide joint intelligence support to operations. The C4ISR Campaign Plan is one of the key documents used to define the context of JIIFC.

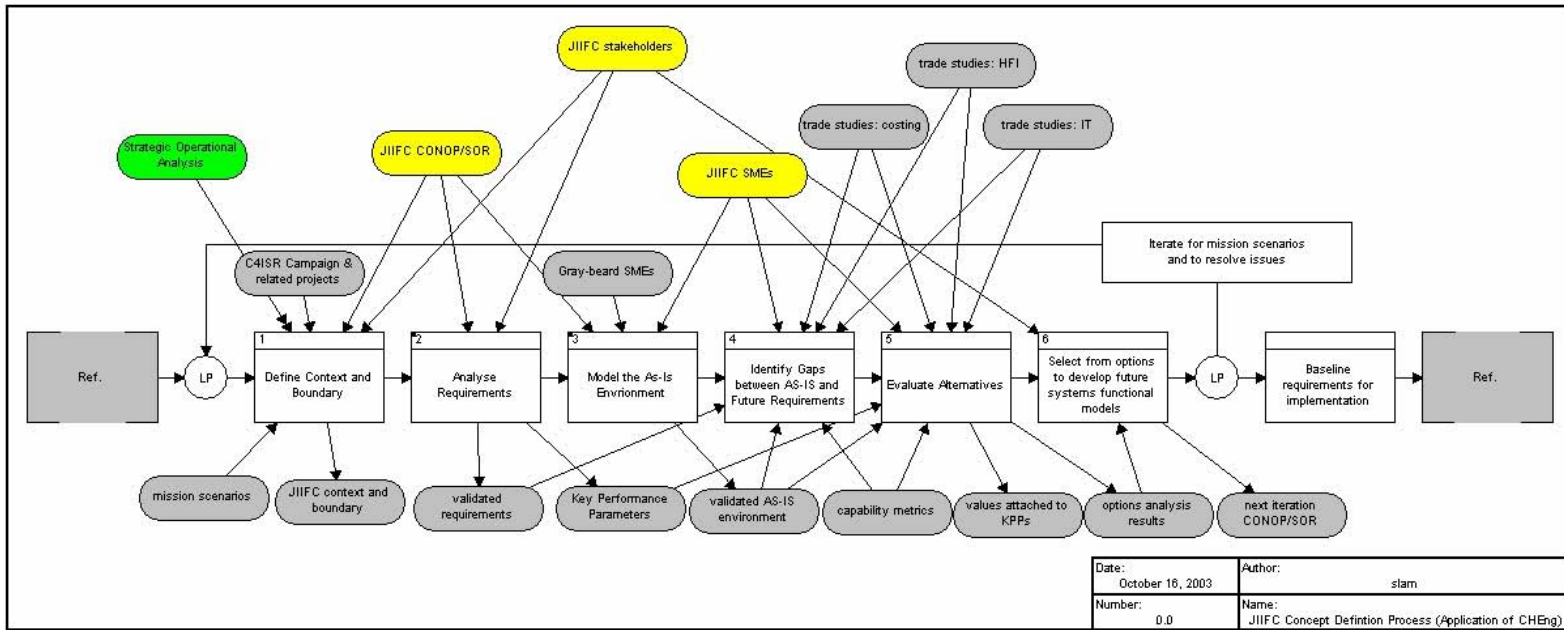


Figure 19: JIIFC Concept Definition Process

5.2.2 Activity 1: Define Context and Boundary

A system's context is a set of entities that can impact the system but not be impacted by the system. These entities impact the system through their inputs and constraints, as well as the outputs of the system must produce to satisfy the external entities. The boundary of the system is defined by the characteristics of these inputs, constraints and outputs of external entities. Unlike in system development phase, in the system concept definition phase, the context and boundary are subjects of study and it is conceivable that the context and boundary may be changed to support a viable concept for the system.

JIFC is an intelligence capability that feeds into situation awareness, which supports of command and control functions. JIFC, being a joint intelligence entity, also needs to interface with many existing intelligence units in the Army, Navy, Air Force and other government departments. All these entities together form the context of JIFC. The activities related to identifying these entities and describing the interaction between them and JIFC will establish the context and system boundary.

5.2.3 Activity 2: Analyze Requirements

The purpose of requirements analysis is to construct operational requirements derived from operational concepts and to validate the requirements through analysis to ensure that operational concepts are faithfully translated into operational requirements. Requirements analysis tools enable concepts and requirements to be represented as individual objects in models and to establish traceability between them. Traceability is the feature that establishes links between concepts and requirements to ensure that all operational concepts have been translated into operational requirements, and that all operational requirements are supported by operational concepts. Traceability also provides an indication of the impact of changing either operational concepts or requirements. When cost elements are attached to requirements, cost impact of requirements and of changes in requirements can be more easily evaluated.

According to IEEE 1220, requirements analysis can be performed more efficiently when requirements are grouped according to their types: functional, operational and design. **Figure 20** shows the current requirements schema for JIFC.

Another aspect of requirements analysis is to identify parameters and metrics needed to validate concepts and requirements. Key Performance Parameters (KPPs) are the important operational capabilities to be implemented and the expected performance measures that affect the decision to invest. The Measures Of Effectiveness (MOE) define, in quantitative terms, how the architecture is to be evaluated on performance, efficiency, effectiveness and resource utilization. The challenge is to define capability metrics that allows us to evaluate a system's contribution to capability requirements. Some suggestions on capability metric are force readiness, which can be

decomposed into many more quantifiable measures.

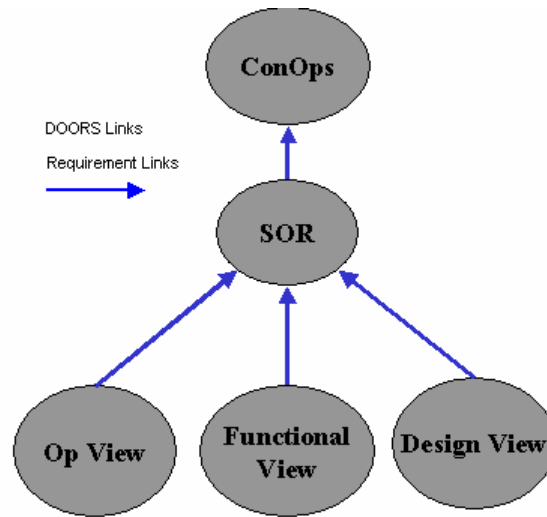


Figure 20: JIIFC Requirements Schema

5.2.4 Activity 3: Model Current Environment

Modelling the current environment creates a baseline to support operational analysis through identifying areas for improvement, the KPPs, and corresponding MOE. Simulation of the operational and functional models can provide an inexpensive and early indication of MOE to validate operational concepts and requirements prior to design and implementation of system components. These metrics often suggest options or alternatives that had not been identified prior to the modelling activity.

According to Schmidt [75], the “as-is” environment is represented by an operational model and a physical model of the existing system (referred to by Schmidt as the “as-is” Integrated Architecture). The operational model identifies the organizational structure, the activities performed by each element of the organization, the information exchanged among the participating organizations, and the resources required to execute the business process. The physical model captures information related to the arrangement of existing facilities/platforms, systems, operators and interfaces. This establishes the linkages necessary to identify how organizational personnel utilize systems to execute the activities and accomplish the business processes defined in the operational model.

JIIFC is a new conceptual capability; and there exist no “as-is” environment for a joint intelligence capability. One alternative is to model the existing disparate intelligence community as a current environment for baseline comparison. Another alternative is to model the existing risk mitigation laboratory configuration as the current environment. Some believe the former does not represent a fair baseline for performance comparison because JIIFC operates on a new concept. Yet, the latter poses some challenges in using “as-

is” environment to identify KPPs, and related metrics, and areas for improvement since the lab setting is not yet operational and no data can be collected based on the past operational experience. As a result, the second alternative will rely heavily on the inputs from subject matter experts and simulation to provide necessary data to support both operational analysis as well as the gap analysis between “as-is” and future requirements. This could also be augmented by the use of the ConOps and SOR to identify KPPs and to establish threshold (minimum acceptable) performance values and objective (goals for achievement) values for those KPPs and then develop through analysis MOE for the KPPs. The choice of “as-is” environment will be determined in the next wave of activities.

5.2.5 Activity 4: Analyse Gaps

Gap analysis refers to the activities undertaken to identify the areas of significant differences between the existing capabilities and the future capabilities. The KPPs and MOE identified in the “as-is” environment are compared to those specified in the SOR. This will help to further define areas for improvements, understand the size of the gaps and establish initial thoughts on possible improvement approaches. The SOR should be used to establish priority for these improvements.

5.2.6 Activity 5: Evaluate Alternatives

The goal of this activity is to evaluate the strengths and weaknesses of various alternatives to provide needed capability. The SysEng process provides guidance to evaluate alternatives by means of trade studies, assessing risks and cost/benefit of various options. The MOE identified earlier will be the parameters for comparison.

Simulation plays an important role in this step. If carried out correctly, it could save both time and money during concept definition. In some cases, simulation may be the only way to evaluate a concept without a huge investment in resources.

The JIIFC Process recognises the value of simulation to analyse and validate alternatives. In this use case the CEP Team have demonstrated various simulation tools in support of these analyses. For instance, the use of COREsim [85] to simulate resource utilization so as to identify process bottlenecks; the use of Integrated Performance Modeling Environment (IPME) [62] to estimate human resource requirements based on attributes related to human performance; and the use of OpNet [69] to model and simulate network requirements and equipment costing.

5.2.7 Activity 6: Select Future Architecture for Implementation

The stakeholders are responsible for the selection of the future architecture. However, the selection will be made easier by the accompanying information generated during the whole process. With traceability implemented, stakeholders will be able to assess options more informatively by following

the linkages to trade study reports, engineering data and supporting documents.

5.3 The JIIFC Engineering Environment

The existing JIIFC engineering environment provides essential technology to support the execution of the process. An integrated engineering repository (such as that provided in Interchange and CORE) serves as a central repository for all data and information generated from various activities performed by different domain experts. The CEP Team are currently evaluating both options for the final JIIFC integrated engineering repository.

Presently, the JIIFC Engineering Environment consists of the basic NCEE COTS software, i.e. DOORS, CORE, Rational Rose [43] and Interchange, and a few tools to support domain specific analysis and simulation (as shown in Figure 16). Note that some of the linkage or plug-ins between tools and the central repository are still under development (represented by dotted lines). IPME is a human-systems integration tool for modelling the workload and workspace for JIIFC. The link to address *interoperability issues* refers to the need to integrate engineering data from related projects into the JIIFC environment to ensure future interoperability in a C4ISR environment. Some of this engineering data include architecture models in the Defence Enterprise Architecture (DEA), and other C4ISR projects. These datasets have been created by different tools and the JIIFC engineering team will determine the need for the development of custom links or plug-ins into the integrated engineering database.

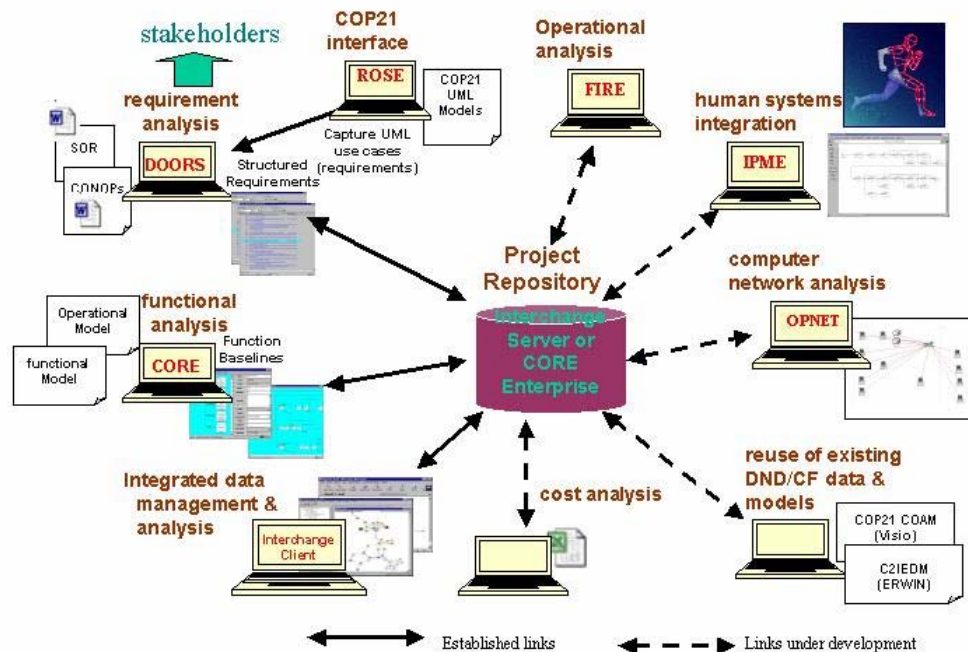


Figure 21: JIIFC Integrated Engineering Environment

5.4 Lessons learned

5.4.1 Results from the JIIFC Workshop

The JIIFC Case Study began in June 2003. On completion of the initial modelling work, a workshop was held in October 2003 to solicit feedback from the JIIFC Project Team on the value of the activities performed during the four-month period. The workshop had four sessions: requirements analysis, functional modelling, trade study on human factor engineering, and trade studies in costing and computer network modelling. Each session consisted of a presentation on the engineering activities in the domain area, and a feedback period in which the participants answer a set of questions related to the CEP.

In the requirements analysis session, the CEP Team demonstrated the concepts of gap analysis and traceability using the information from the ConOps and SOR. We also presented some analysis results, such as dangling requirements, to the participants to illustrate the main benefits of requirements analysis. In the functional modelling session, the CEP Team presented the Task, Process, Exploitation, Dissemination (TPED) process model and illustrated the use of a simulation tool (COREsim) to analyse resources utilization and optimization of processes. In the human factor engineering session, we modelled the application of the TPED process in a scenario that involves open source intelligence analysis. Using this scenario, human factor engineers were able to demonstrate realistically the type of analyses they could perform using IPME to provide values to JIIFC. In the costing trade study and computer network modelling session, we have identified areas that cost analysis will provide benefits to JIIFC concept definition, and the use of OpNet to support network M&S.

In short, the members of the JIIFC team provided many constructive comments throughout the workshop. At the end of the workshop, the CEP Team solicited the participants' overall acceptance of the CapDEM approach. The response revealed a strong support for the JIIFC Process used in JIIFC case study.

5.4.2 The Application of TP4 CEP Working Draft

In the JIIFC Case Study, the CEP Team was able to adapt the TP4 CEP Working Draft to support JIIFC concept definition activities. Initially, we expected the TP4 CEP Working Draft to be a well-developed process. The CEP Team soon realized that the TP4 CEP Working Draft is still evolving. Nonetheless, the high level description of the processes served well as the framework to adapt to the needs of the JIIFC project. The lack of details in the TP4 CEP Working Draft document also provided us the freedom to adapt the process to address specific areas of focus for JIIFC.

Although the TP4 CEP Working Draft documentation lacked details, it is built from the IEEE 1220 standard for SysEng process and the DoD AF. IEEE 1220 provides a very detailed description of a SysEng process that

supports engineering for the SLC. The DoD AF and its architecture data model (CADM) enforce the architecture approach to ensure interoperability. These two documents serve as the foundation documents for development of the JIIFC Process.

In this case study, our objective is to apply the process to support concept definition activities. A review of the IEEE 1220 indicated that the SysEng process begins at system development. Quoting from IEEE 1220:

“The SysEng process applies throughout the SLC to all activities associated with product development, test, manufacturing, training, operation, support distribution, disposal and human SysEng.” Although the document addresses system definition, the focus is on “ [defining] system products required to satisfy operational requirements.”

In concept definition, the focus is on providing a structured approach for users to explore possible solution strategies to a problem by assessing their feasibility, utilities, and identifying the limitations, constraints and risks. For IEEE 1220, the outcome is a well-designed system. For concept definition the outcome is a well-defined ConOps and operational requirements documents. This is not to say that IEEE 1220 is not useful to concept definition. Contrarily, the CEP Team realised that with a shift of focus, many of the activities still apply. In fact, in order to be able to validate a concept, we need to perform systems design and development to an extent that will provide enough understanding of the characteristics of a potential solution (e.g. system prototyping).

The emphasis on concurrent engineering of SLC is key to SysEng. It applies to concept definition as much as to SysEng. Consequently, trade studies in resource requirements, costing and technology forecast for the SLC are crucial in validating a concept. The challenge of life cycle management becomes enormous in CE because capability is almost always supported by a SoS and the life cycle of these individual systems must be managed to maintain desired capability. Having a well-defined process that is adopted by all systems owners is a starting point. A well-designed integrated engineering environment, such as the NCEE, will be a technological enabler.

The US NCEE provided the JIIFC case study with an initial set up for an integrated engineering environment. The environment allows us to implement traceability across all engineering data and information. CEP Team gained appreciation of such an environment as we explore the context for, and the makeup of JIIFC. The large number of stove-pipe systems that JIIFC must integrate to provide joint fusion capability will require considerable engineering and management effort. We believe the integrated engineering environment is essential to support engineering and management of concept definition as well as system design and development.

Initial Process Assessment based on JIIFC case study

Using the experience from the JIIFC case study, the CEP Team was able to provide a preliminary assessment of the TP4 CEP Working Draft using the proposed assessment criteria. The CEP Team must emphasize that the

following assessment applies to the JIIFC case study and related activities only. More importantly, it assesses the process as it is applied to support concept definition.

Table 3: Analysis of the TP4 CEP Working Draft as Applied to JIIFC

Quality	Comments
Relevance	CapDEM-JIIFC team was able to adapt the process to meet JIIFC requirements.
Compliance to Standards	CapDEM-JIIFC team follows the IEEE 1220; DoD AF as foundation documents when interpreting the proposed process.
Functional Quality	With the understanding that the proposed process is an overview, the CapDEM JIIFC team found this high-level guideline served as a useful starting point. CEP Team has added the context/boundary definition and Requirements analysis in the JIIFC process.
Technical Quality	The NCEE toolset received a mixed review. DOORS and Rational Rose are both well-used and mature products. CORE, though relatively new, is well received by many systems engineers and analysts. Our technical team is still struggling with Interchange. Interchange is the most significant piece in the NCEE, without which the Integrated Engineering Concept will be disabled.
Effectiveness	CapDEM JIIFC team was able to follow the process to develop the "as-is" integrated architecture. CEP Team also applied IEEE 1220 to identify issues related to requirements in the SOR.
Efficiency	To be evaluated
Usability	Learning curve is not steep to systems engineers because the process does build on general SysEng standards and strong common sense. However, the CADM is relatively intensive document and the use of it still needs to be assessed.
Impact	JIIFC project team has chosen to use the JIIFC process to continue concept definition activities.
Maturity	No known example. JIIFC may well be the first one in North America if not among the TTCP countries.
Continuity	To be evaluated
Cost	To be evaluated.

6. Conclusion

This report has presented results of the CEP Team at the end of 2003. Since April 2003, the CEP Team has conducted many activities to achieve its mandate. Each team members received training on SysEng and TP4 CEP Working Draft and tools. A practical and theoretical analysis of TP4 CEP Working Draft was performed. A literature study covering SoS, SBA, SysEng standards and US acquisition was conducted.

Some perspectives of CEP have been investigated. The first perspective of CapDEM TDP and the TP4 CEP Working Draft, as described by Schmidt, have a good but too limited (or too concise) definition of a process and CE. Others investigations have been necessary to complete the understanding of CEP. Possible scopes of the CE, possible forms of the process enabling this concept and specific objectives of the CE have been identified. Finally, some candidate solutions that already applied to solving similar problems have been presented/introduced.

Many solutions such as concepts, frameworks, standards, processes and tools have been presented/introduced. They can contribute to reach the CEP objective. However, most of them are conceived in the United-States/have a US flavour and their context of use is different. Even though all these solutions can help to accomplish CEP objective, for some of these technologies, it is hard to determine requirements behind them. Then it is hard to understand their strengths and weaknesses and to import only the most appropriate elements in CEP. The solutions are difficult to compare and, thus, to evaluate. An important next step will be to evaluate and select, in part or in totality, of already working solutions, the creation of new technologies if needed and the integration of selected and newly created solutions into a coherent and synchronized solution. For that purpose, overlaps, gaps or inconsistencies between them will have to be eliminated. Even if two solutions complete each other, their integration remains a challenge.

The analysis of the TP4 CEP Working Draft has highlighted some main strengths: a standard approach, known references and simulation usage. The process follows a standard and common sense approach similar to Enterprise Architecture concepts and is the combination of DoD Acquisition Policies. The process requires the development of operational and physical models that could be simulated. The main limitation is the activity description. The level of details of each activity varies a lot; for instance, each activity description could include some basic standard information. The TP4 CEP Working Draft is built to address the US acquisition problem. Some work is required to better understand the specificities of DND/CF's acquisition process and its problematic. The process has its stand now leaves room for interpretation, is not self-understanding and self-applicable. Considering these facts, the process is not ready to be used and institutionalized. On the other hand, the TP4 CEP Working Draft general approach being a standard one provided very good input to start the development of the Canadian CEP.

The JIIFC case study provided a realistic setting for the CEP Team to partially evaluate the TP4 CEP Working Draft. The JIIFC use case began in June 2003. After

the initial wave of modelling and analysis activities, a workshop was held in October 2003 to solicit feedback from the JIIFC project team on their perceived value of applying this process to support JIIFC concept definition phase. The project team confirmed their strong acceptance of this CapDEM approach through many constructive comments throughout the workshop.

The CEP Team has successfully achieved the goal of this case study in a 5 months period. At the end of October 2003, we were able to evaluate the TP4 CEP Working Draft and toolsets. The CEP Team concluded that the TP4 CEP Working Draft served adequately as a high-level guideline for the development of the JIIFC process. Nonetheless, the RDA CHENG CEE toolset has presented some challenges to the JIIFC use case due to the high degree of customization required to support projects, hence the time required to set up an efficient and effective CEE.

- The CEP Team has achieved the goal of the JIIFC case study from June to October 2003.
- The JIIFC process should be employed for the C4ISR Campaign to provide more effective context for JIIFC.
- The JIIFC process should define and support an effective interface with the Project Management Process to augment the value added to the decision-making at the capability management level.

The JIIFC process should also define and support an effective interface with the M&S process to facilitate the reuse of data to support simulation in concept analysis and validation.

Way ahead

This document demonstrated that the scope of CEP could be very large. Many questions remain to be answered before defining completely the scope of CEP. Many of them cannot be answered as long as specific requirements of the Canadian capability development community and the identification of actual acquisition problems are not known. Based on a better understanding of the actual situation of the Canadian acquisition, the time constraints of the TPD and the risks associated to develop CEP for a specific scope, CEP Team will be able to answer to these questions and to better scope CE. Finally, some questions will fall within the competence of stakeholders to facilitate institutionalization and resources prioritization. Since the problem space of the CE is very large, an initial solution should tackle only a portion of the problem.

Based on the knowledge acquired during this first nine months, the next priority for the CEP Team is to get a very good understanding of the current deficiencies of the Canadian process. As a first step, the Canadian current situation, “as-is”, will be studied, regarding mainly the current DND project approvals process. In addition, other DND initiatives related to the CEP will be examined. In parallel, a kind of International current situation will be worked out, looking at what is being done outside Canada. From these two “current situations” and lessons learned from two CapDEM case studies, JIIFC and ISR Maritime, CEP Version 1, the “to-be” will be elaborated and tested with potentially subsets of the case studies.

7. References

1. Acquisition Community Connection. Available at www.acq.osd.mil/dpap/Docs/FAQs%20--%20SoS%20&%20FoS.doc. December 2003.
2. Arnald, S, and Cook, S., *Developing a Coalition Systems Engineering Process*, INCOSE Insight Vol. 5 Issue 3, October 2002. pp. 7-9.
3. Beckerman, L.P., "Application of Complex Systems Science to Systems Engineering", *Journal of Systems Engineering*, 3(2), 2000.
4. Blue Ribbon Panel. *Report of the Blue Ribbon Panel on FAA Acquisition Reform*. 1996.
5. Buede, D.M., *The Engineering Design of Systems: Models and Methods*. John Wiley & Sons. Inc., 2000.
6. C2I2 JCAT Secretariat, *Canadian Forces C4ISR Campaign Plan*, Interim Report, UNCLASSIFIED, 2003.
7. C4ISR Architecture Working Group, *C4ISR Architecture Framework*, Version 2.0, Department of National Defence, USA, 1997.
8. CapDEM TDP, Project Correspondence (e-mails).
9. CapDEM Management Team, *Project Charter - Collaborative Capability Definition, Engineering and Management (CapDEM) Technical Demonstration Project*, 25 February 2003.
10. CapDEM CEP Team, *CapDEM CEP Team - Sub-Project Charter*, Internal document, June 2003.
11. CapDEM CEP Team, *CapDEM TDP: Kick-off of the CEP&CIAP workstreams*, DRDC Valcartier, 28 April 2003.
12. CapDEM Management Team, *Project Implementation Plan - Collaborative Capability Definition, Engineering and Management (CapDEM) Technical Demonstration Project*, 5 May 2003, 49 pp.
13. Catalano, D., *DoD 5000: Another One Bites the Dust - Interim Guidance Highlights*, 2002.
14. Center for Technology in Government - University at Albany / SUNYA Survey of System Development Process Models, 1998. Available at http://www.ctg.albany.edu/publications/reports/survey_of_sysdev
15. Chen, P., and Clothier, J., *Advancing Systems Engineering for Systems-of-Systems Challenges*, *Journal of The International Council on Systems Engineering*, 6(3), pp. 170-183, 2003.
16. (The) Chief Information Officers Council, *A Practical Guide to Federal Enterprise Architecture version 1.0*, February 2001.
17. (The) Chief Information Officers Council, *Federal Enterprise Architecture Framework version 1.1*, September 1999.

18. Chief of Naval Operations, Department of Navy and Marine Corps, *Naval Transformation Roadmap*.
19. Chief of Staff, *CJCSI 3170.01C*, 2003.
20. Cook, S.C., "On the Acquisition of Systems of Systems", *In Proceedings of 11th Annual Symposium INCOSE 2001*, Melbourne, Australia, 2001.
21. Crisp, H.E., and Chen P., "Coalition Collaborative Engineering Environment", *INCOSE Insight* Vol.5 Issue 3. October 2002. pp. 13-15. A publication of the International Council on Systems Engineering.
22. Crispin, R., *CapDEM/JIIFC Workshop #1: October 21, 2003*, DSS Report, October 22, 2003.
23. Dahmann, J., *Role of M&S in Support of the New DOD Requirements and Acquisition Processes*, 2003.
24. Defense Finance and Accounting Service (DFAS), System Life Cycle (SLC), 2003. Available at <http://www.dfas.mil/technology/pal/ssps/slc/index.htm>
25. Department of the Treasury Chief Information Officer Council, *Treasury Enterprise Architecture Framework*, Version 1, July 2000.
26. Dickerson, C.E., "Coalition Integrated Air Picture Architecture Description", *NDIA Systems Engineering Conference*, October 21-24 2002. Available at <http://www.dtic.mil/ndia/2002systems/dickerson2a5.pdf>
27. DND - Symposium Working Group, *Creating the CF of 2020. Concept Development and Experimentation and Modelling and Simulation*, 1 November 2000.
28. DoD Architecture Framework Working Group, *DoD Architecture Framework Version 1.0 Volume I: Definitions and Guidelines*, 15 January 2003.
29. DoD Architecture Framework Working Group, *DoD Architecture Framework Version 1.0 Volume II: Product Description*, 15 January 2003.
30. DoD Architecture Framework Working Group, *DoD Architecture Framework Version 1.0 Volume III: Appendices*, 15 January 2003.
31. DoD, *Large Scale System Engineering Process (LSSEP) – Draft*.
32. DoD, *Transformation Planning Guidance*, 2003.
33. DoD, *Quadrennial Defense Review Report*, September 30, 2001.
34. DoD, *DoD Directive 5000.1*, 2003.
35. DoD, *DoD Instruction 5000.2*, 2003.
36. DoD, *DoD Regulation Guidance 5000.2-R*, 2002.
37. DoD, *DoD Instruction 5000.2A Defense Acquisition Guidebook*.
38. Department of the Army. *Requirements - TEMAC T&E Refresher Cours*, 27 June 2003.
39. EIA, *EIA 632 Standard: Processes for Engineering a System*, January 1999.

40. Frequently Asked Question: SoS and FoS. Available at <http://www.acq.osd.mil/dpap/Docs/FAQs%20--%20SoS%20&%20FoS.doc>
41. Hawthorne, S., and Lush, R., “Evolutionary Acquisition and Spiral Development”, *The Journal of Defense Software Engineering*, August 2002.
42. IBM Rational, Rational Unified Process (RUP). Available at <http://www.rational.com/>
43. IBM, Rational Rose, 2003. Available at <http://www.rational.com>
44. IEEE Std 1220-1998, *Standard for Application and Management of the Systems Engineering Process*, IEEE Standards Department, 445 Hoes Lane, P.O. Box 1331 Piscataway, NJ 08855-1331, USA.
45. IEEE Std 1362-1998, *IEEE Guide for Information Technology—System Definition—Concept of Operations (ConOps) Document - Description*, IEEE Standards Department, 445 Hoes Lane, P.O. Box 1331 Piscataway, NJ 08855-1331, USA.
46. Investment Cost Analysis Branch of FAA, *FAA Life Cycle Cost Estimating Handbook*, June 3, 2002.
47. ISO, *ISO/IEC 12207; Standard for Information Technology - Software Life Cycle Processes*, 1995.
48. ISO, *ISO/IEC 15288; Systems Engineering—System Life Cycle Processes*, October 2002.
49. Lt Col Jackson J.A., Lt Col Jones, B.L., Maj Lehmkuhl, L.J., *Operational Analysis: Air Force 2025*, May 1996. Available at <http://www.au.af.mil/au/2025/volume4/chap03/vol4ch03.pdf>
50. JIIFC Project Team, *Canadian Forces Joint Information Intelligence Fusion Capability*. Version 6.0, 15 October 2002.
51. JIIFC Project Team, *Joint Information Intelligence Fusion Capability: Statement of Operational Requirements*, DSP No. 0000624, UNCLASSIFIED, 2003.
52. JP Rushing Consulting, 2003. Available at http://www.jprushing.com/ECM/Enterprise_Architecture.asp
53. Kaffenberger, R., and Fisher, J., “Designing Systems-of-Systems Without Getting Trapped in the Subsystem Maze”, *In Proceedings of 11th Annual Symposium INCOSE 2001*, Melbourne, Australia, 2001.
54. Koslov, A.E., *Future State Enterprise Technical Architecture Version 1.1*, U.S. Department of Housing and Urban Development, Office of the Chief Information Officer, Enterprise Architecture Program, 2003.
55. Kröll, P., and Kruchten, P., *Rational Unified Process Made Easy, The: A Practitioner's Guide to the RUP*, Addison-Wesley Professional, (ISBN: 0321166094), April 2003.
56. Kruchten, P., *The Rational Unified Process: An Introduction*, Addison-Wesley Pub Co; 2nd edition, 2000.

57. Laurendeau, D., *Ingénierie des systèmes complexes – Méthodologie de design*, for Canadian CapDEM TDP Team, May 20-21, 2003.
58. Leclerc, J., *CHEng Capability Engineering Process Assessment Report*, Technical report, CGI, 2003.
59. Maier, M.W., “Architecting Principles for Systems-of-Systems”, *Systems Engineering*, Vol. 1, Issue 4, pp. 267-284, 1998.
60. Maier, M.W., “Architecting Principles for Systems-of-Systems”, *In Proceedings of 6th Annual Symposium INCOSE 1996*, pp. 567-574, 1996.
61. Malhotra, Y., *Enterprise Architecture: An Overview*, BRINT Institute, 1996. Available at <http://www.brint.com/papers/enterarch.htm>
62. Micro Analysis and Design, Integrated Performance Modelling Environment (IPME). Available at www.maad.com
63. Morais, B.G., and Mar, B.W., “Maximizing the Systems Aspects of Systems Engineering”, *Tutorial 06 at the 13th Annual Symposium INCOSE*, 2003.
64. Newbern, D., and Nolte, J., “Engineering of Complex Systems: Understanding the Art Side”, *In Proceedings of the 8th Annual Symposium INCOSE 1998*, 1998.
65. Office of the Secretary of Defense, *Defense Planning Guidance*, 2002.
66. Object Management Group (OMG), *OMG Unified Modeling Language Specification. Formal Specification v 2.0*, June 2003. <http://omg.org>
67. Object Management Group (OMG), *OMG Unified Modeling Language Specification. Formal Specification v 1.4*, September 2001. <http://omg.org>
68. Office of the Assistant Secretary of Defense, *All-DoD Core Architecture Data Model (CADM). Volume I - Overview Description*, Interim Draft Report, 28 August 2003.
69. OPNET Technologies Inc. Available at www.opnet.com
70. Maj. Pogue, C., and Dr Vallerand, A., “A Conceptual Model of Military Capabilities and an Integrating Functional Architecture to Facilitate Military Capability-Based Planning”, in *Proceedings of the Summer Simulation Multiconference*, Montréal, Qc, Canada, July 20-23, 2003.
71. *Proceedings of the 13th Annual International Symposium INCOSE*, June 29-July 3, 2003. <http://www.incose.org/symp2003/>
72. Quinlan, R., “Force Integration Initiatives”, *NDIA Systems Engineering Conference*, October 21-24 2002. Available at <http://www.dtic.mil/ndia/2002systems/quinlan1c2.pdf>
73. Rebel, J.M., “Applying Systems Engineering To Family-of-Systems Acquisition”, Presented at the NDIA Systems Engineering Conference, 2002.
74. Rumbaugh, J., Jacobson, I., and Booch, G., *The Unified Modeling Language Reference Manual*, Addison-Wesley Pub Co, 1998.
75. Schmidt, R., *Overview of the Capability Engineering Process (Cheng Process)*, prepared for TTCP JSA TP4, 10 June 2003.

76. Schmidt, R., *Course Notes, Vol. 1 and Vol. 2*, for Canadian CapDEM TDP Team, May 27-30, 2003.
77. Sheard, S.A., and Dr Lake, J.G., *Systems Engineering Standards and Models Compared*, 1998. Available at <http://www.software.org/pub/externalpapers/9804-2.html>
78. Telelogic, DOORS, 2003. Available at <http://www.telelogic.com/>
79. The Open Group. TOGAF. Available at <http://www.opengroup.org/togaf/>
80. Trident Systems, Interchange, 2003. Available at <http://www.interchangese.com/>
81. UML, 2004. Unified Modeling Language™ (UML®), Version 1.4. Available at <http://www.omg.org>
82. U.S. Army. *US Army Transformation Roadmap*.
83. U.S. Air Force. *The USAF Transformation Flight Plan*.
84. USD (AT&L). *Memo on Evolutionary Acquisition*. 12 April 2002.
85. Vitech Corporation, CORE Product Family, 2003. Available at <http://www.vtcorp.com/>
86. Dr Walker, R., *Towards Defence Capability Management: A Discussion Paper*, June 2002.
87. Walhl, K., Mades, J., and Pike, S., “Single Integrated Air Picture”, *The Marine Corps Systems Command's Battlespace Management Air Defense Systems Industry Day*, Liversedge Hall, Quantico, VA, 11 April 2002. Available at [http://www.marcorsyscom.usmc.mil/BMADSarchive/2002industryday.nsf/MyView/223EEB385B1FC76F85256D6C0046D478/\\$File/SIAP.ppt](http://www.marcorsyscom.usmc.mil/BMADSarchive/2002industryday.nsf/MyView/223EEB385B1FC76F85256D6C0046D478/$File/SIAP.ppt)
88. Zachmann Institute for Framework Advancement, *Zachmann Framework*. Available at <http://www.zifa.com/>

Annexe A

Overview of the Capability Engineering Process

Prepared for: TTCP JSA TP4

by Richard Schmidt, Systems Technology, Inc, 10 June 2003

Purpose:

This document provides an overview of the Capability Engineering Process based on industry standards for Systems Engineering. It abstracts the principles and concepts of the Systems Engineering Process as it applies to Defense “System-of-Systems” capability planning and engineering. A review of the recently published DoD Directive 5000.1 and DoD Instruction 5000.2 is underway to assess the compatibility of this Capability Engineering Process with the new DoD Acquisition Guidance.

1. Defining the Capability Engineering Process

The Capability Engineering Process bridges the Operational Analysis activity and the System Acquisition Community by analyzing the Current “As-Is” Integrated Architecture (System-of-System), establishing the Strategic Vision for how the war fighting capability will be evolved, and developing the Transformation Roadmap to address Force Structure changes, Evolutionary Acquisition Strategy, and Force Training/Transition Plan, and associated Investment Strategy. The result of this process is to provide a transformation roadmap which is achievable, recognizes the risk associate with the capability evolutionary acquisition program, and how the force training/transition will establish the initial and full operational capability. Figure 1 describes the Capability Engineering Process which leads to a System-of-System Evolutionary Acquisition strategy for evolving Operational Capabilities over a long-term timeframe.

Capability Engineering Process

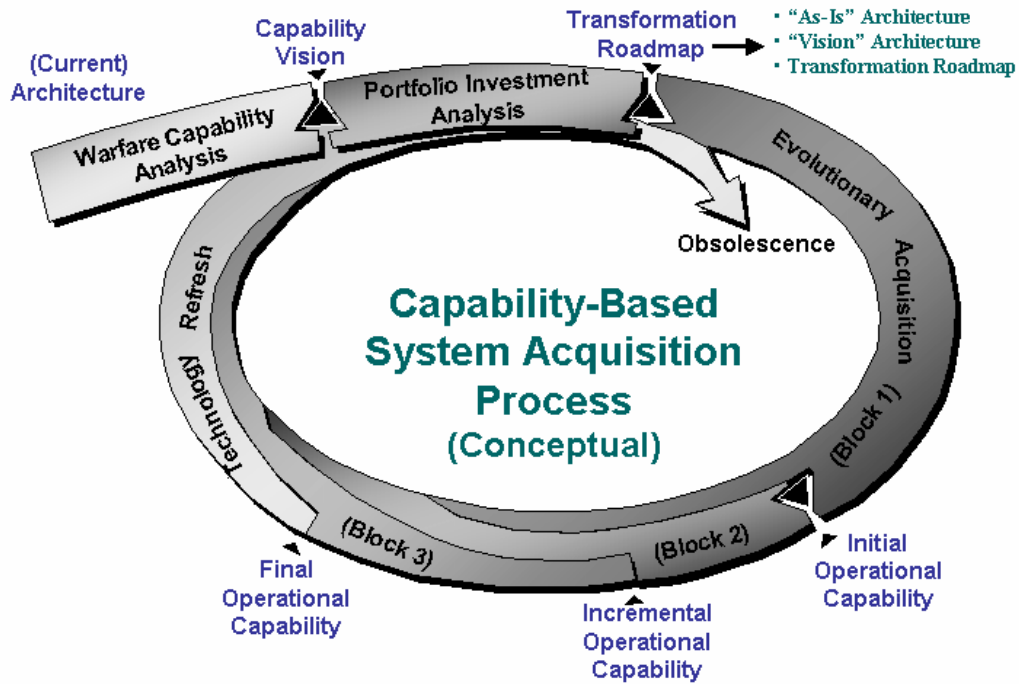
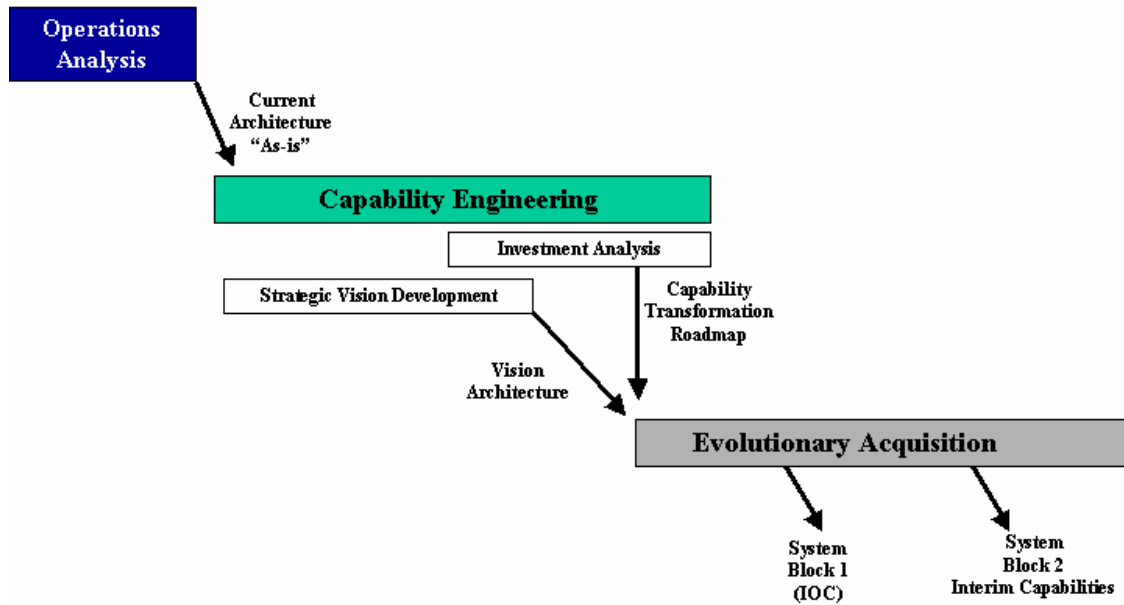


Figure 2 depicts how the Capability Engineering Process bridges the Operational Analysis and Evolutionary Acquisition processes.



2. Application of the Systems Engineering Process

The systems engineering process provides the framework for developing the “As-is” and “Vision” Business Architectures, assessing the availability of systems, components and technologies which can be leveraged to provide new Operational capabilities. The SysEng Process is applied iteratively to:

- a. Define the “As-is” Integrated Architecture
- b. Assess the “As-is” Integrated Architecture to identify areas which can be improved
- c. Develop the Strategic Vision to Guide Capability Evolution
- d. Develop the “Vision” Integrated Architecture
- e. Assess the costs, schedule and risks associated with implementing the “Vision” Integrated Architecture, and
- f. Establishing the Transformation Roadmap for Acquiring Systems or modifying Business Practices to achieve the Capability Objectives identified in the Strategic Vision.

2.1 Define the “As-is” Integrated Architecture

The “As-is” Architecture represents the current Business Architecture and the inherent “capabilities” this architecture provides. This Architecture is described in terms of Organizational Structure, roles & responsibilities, Business Processes, and the “modernization” associated with the Organizations in terms of systems and equipment. The Architecture is documented in an Operational Model (describing the business processes), and the Physical Model (describing the Facilities/platforms, systems, interfaces and operators).

2.1.1 Capture the “As-is” Operational Model

The Systems Engineering Process begins with understanding the customer expectations, identifying the Business Process and developing an operational model of the “As-Is” Architecture. This operational model identifies the organizational structure, the activities performed by each element of the organization, the information exchanged among the participating organizations, and the resources required to execute the Business Process.

Each of the relevant processes or activities are decomposed to a level of functionality which can be associated/allocated to humans, or systems. From this Operational model the DOD Architecture Framework Operational Views (OVs) can be generated except the OV-6c (State Transition). In addition, some of the System Views which relate Operational Activities to System Functions can be generated.

2.1.2 Capture the “As-is” Physical Model

The Physical Model depicts the arrangement of existing facilities/platforms, systems, operators and interfaces. This establishes the linkages necessary to identify how organizational personnel utilize systems to execute the activities and accomplish the business processes defined in the Operational Model. From this Physical Model the remainder of the DOD Architecture Framework System Views (OVs) can be generated.

2.1.3 Identify the Measures of Effectiveness

The Measures of Effectiveness define how the architecture is to be evaluated in terms of performance, efficiency, effectiveness, and resource utilization.

2.1.4 Identify Areas of Opportunity for Improvement

These measures provides the basis for evaluating the “As-is” Architecture and determining where opportunities for improvement exists. This analysis provides the information for identifying the alternatives available for improving the Architecture. The Systems Engineering Process establishes a generic approach for conducting trade-studies, assessing the risks and evaluating the cost/benefits associated with each alternative.

2.2 Establish the Strategic Vision

Based on the evaluation of alternatives, a strategic vision should be prepared which addresses the long-term Capability Objectives for improving the Architecture in terms of Operating Procedures (Doctrine & Tactics), Organizational Realignment, or System Enhancements/Evolution. This activity must be accomplished concurrently with the initial development of the “Vision” Architecture to identify, evaluate, and select the preferred “Vision” Architecture solution.

This Strategic Vision provides the guidelines for establishing the “Vision” Architecture and should address the following topics:

2.2.1 Evaluate Availability of Technology

2.2.2 Evaluate Doctrine & Tactic Evolution

2.2.3 Evaluate Force Structure Evolution

2.2.4 Document the Strategic Vision

Once the Alternative “Vision” Architectures have been evaluated, the preferred solution is selected and the strategic vision is documented to provide the long-term strategy for evolving the Business Architecture. This strategic vision guides the development of the Transformation Roadmap which establish the strategic “plan” and investment profile for accomplishment of the evolution of the Business Architecture.

2.3 Develop the "Vision" Integrated Architecture

The “Vision” Architecture represents the current Business Architecture and the inherent “capabilities” this architecture provides. This Architecture is described in terms of Organizational Structure, roles & responsibilities, Business Processes, and the “modernization” associated with the Organizations in terms of systems and equipment. The Architecture is documented in an Operational Model (describing the

business processes), and the Physical Model (describing the Facilities/platforms, systems, interfaces and operators).

2.3.1 Identify Candidate "Vision" Architecture Alternatives

There are always multiple approaches for improving the Business Processes, so the various alternatives should be identified as candidates for consideration.

2.3.2 Evaluate Candidate Alternatives for Feasibility

The initial candidates should be evaluated to reduce the number of alternatives selected for detailed evaluation due to feasibility, costs, or performance considerations.

2.3.3 Select Alternative(s) for Concept Development

It may be necessary to pursue multiple alternative "Vision" Architectures to assess the "Value-added" with each alternative, and select the best approach for evolving the Business Architecture. Initial Conceptual Architectures may be developed to support evaluation.

2.3.4 Develop Alternative(s) Operational Model

The Operational Model should reflect the organizational changes (force structure) and process alterations desired to provide improved capabilities. Each of the relevant processes or activities are decomposed to a level of functionality which can be associated/allocated to humans, or systems. From this Operational model the DOD Architecture Framework Operational Views (OVs) can be generated except the OV-6c (State Transition). In addition, some of the System Views which relate Operational Activities to System Functions can be generated.

2.3.5 Develop Alternative(s) Physical Model

The Physical Model depicts the arrangement of legacy and new facilities/platforms, systems, operators and interfaces. This establishes the linkages necessary to identify how organizational personnel utilize systems to execute the activities and accomplish the business processes defined in the Operational Model. From this Physical Model the remainder of the DOD Architecture Framework System Views (OVs) can be generated.

2.3.6 Evaluate Alternative(s) Architecture Cost/Effectiveness

The Alternative are evaluated to assess their "value-added" to the enterprise, assess risks to implementation, and provide a analytical basis for decision making.

2.3.7 Select & Document the Preferred Alternative

The preferred solution is selected and refined to resolve any outstanding issues/risks. The architecture for the selected alternative is finalized, and document.

2.4 Establish the Transformation Roadmap

The Transformation Roadmap establishes the strategic plan for accomplishing the strategic vision.

2.4.1 Identify the Organizational (Force) Structure Evolution Plan

This section of the Transformation Roadmap addresses the changes to the Organizational structure and associated Roles and Responsibilities, and the time frame when these changes are to be implemented.

2.4.2 Establish Capability Evolution Objectives

This section of the Transformation Roadmap addresses the evolution of Capabilities/Performance objectives over time with each incremental step in evolving the Integrated Architecture.

2.4.3 Establish the Evolutionary Acquisition Roadmap (Risk Mitigation)

This section of the Transformation Roadmap addresses the Evolutionary Acquisition Program(s) which will be established and authorized to realize the Capability Objectives and Strategic Vision.

2.4.4 Establish the Force Training & Transition Plan

This section of the Transformation Roadmap addresses the Force Readiness actions required to train and integrate systems/equipment items into the operational forces. This may include involving the Operational Forces in the Testing Programs, and the establishment of the training programs and associated systems.

2.4.5 Establish the Investment Plan

This section of the Transformation Roadmap addresses the Long-term funding profile for the Evolutionary Acquisition program(s) and should lead to a stable funding commitment by Acquisition Executive to realize the Capability Objectives.

Distribution List

INTERNAL DISTRIBUTION

- 1 - Director General
- 3 - Document Library
- 1 - Head, System of systems
- 1 - F. Bernier (author)
- 1 - M. Couture (author)
- 1 - G. Dussault (author)
- 1 - C. Lalancette (author)
- 1 - F. Lemieux (author)
- 1 - M. Lizotte (author)
- 1 - M. Mokhtari (author)
- 1 - J. C. St-Jacques

EXTERNAL DISTRIBUTION

- 1 – DRDKIM (PDF File)
- 1 - Director General Research and Development Programs
- 1 - Assoc DGRDP
- 1 - Director Science and Technology (C4ISR)
- 1 - DST C4ISR 2
- 2 - DRDC Ottawa, Document Library
- 1 - DRDC Ottawa, Deputy Director General
- 1 - DRDC Ottawa, Head/FFSE
- 3 - DRDC Ottawa, J. Pagotto
- 1 - DRDC Ottawa, S. Lam (author)

FICHE DE CONTRÔLE DU DOCUMENT

1. PROVENANCE (le nom et l'adresse) Defence R&D Canada Valcartier 2459 Pie-XI Blvd. North Val-Bélair, QC G3J 1X8	2. COTE DE SÉCURITÉ (y compris les notices d'avertissement, s'il y a lieu) Sans classification	
3. TITRE (Indiquer la cote de sécurité au moyen de l'abréviation (S, C, R ou U) mise entre parenthèses, immédiatement après le titre.) CapDEM - Toward a capability engineering process: A discussion paper (U)		
4. AUTEURS (Nom de famille, prénom et initiales. Indiquer les grades militaires, ex.: Bleau, Maj. Louis E.) Bernier, F., Couture, M., Dussault, G., Lalancette, C., Lam, S., Lemieux, F., Lizotte, M., Mokhtari, M.		
5. DATE DE PUBLICATION DU DOCUMENT (mois et année) September 2005	6a. NOMBRE DE PAGES 65	6b. NOMBRE DE REFERENCES 88
7. DESCRIPTION DU DOCUMENT (La catégorie du document, par exemple rapport, note technique ou memorandum. Indiquer les dates lorsque le rapport couvre une période définie.) Rapport Technique		
8. PARRAIN (le nom et l'adresse)		
9a. NUMÉRO DU PROJET OU DE LA SUBVENTION (Spécifier si c'est un projet ou une subvention) 15as (Numéro de projet)	9b. NUMÉRO DE CONTRAT	
10a. NUMÉRO DU DOCUMENT DE L'ORGANISME EXPÉDITEUR TR 2004-230	10b. AUTRES NUMÉROS DU DOCUMENT N/A	
11. ACCÈS AU DOCUMENT (Toutes les restrictions concernant une diffusion plus ample du document, autres que celles inhérentes à la cote de sécurité.) <input checked="" type="checkbox"/> Diffusion illimitée <input type="checkbox"/> Diffusion limitée aux entrepreneurs des pays suivants (spécifier) <input type="checkbox"/> Diffusion limitée aux entrepreneurs canadiens (avec une justification) <input type="checkbox"/> Diffusion limitée aux organismes gouvernementaux (avec une justification) <input type="checkbox"/> Diffusion limitée aux ministères de la Défense <input type="checkbox"/> Autres		
12. ANNONCE DU DOCUMENT (Toutes les restrictions à l'annonce bibliographique de ce document. Cela correspond, en principe, aux données d'accès au document (11). Lorsqu'une diffusion supplémentaire (à d'autres organismes que ceux précisés à la case 11) est possible, on pourra élargir le cercle de diffusion de l'annonce.)		

SANS CLASSIFICATION

COTE DE LA SÉCURITÉ DE LA FORMULE
(plus haut niveau du titre, du résumé ou des mots-clefs)

13. SOMMAIRE (Un résumé clair et concis du document. Les renseignements peuvent aussi figurer ailleurs dans le document. Il est souhaitable que le sommaire des documents classifiés soit non classifié. Il faut inscrire au commencement de chaque paragraphe du sommaire la cote de sécurité applicable aux renseignements qui s'y trouvent, à moins que le document lui-même soit non classifié. Se servir des lettres suivantes: (S), (C), (R) ou (U). Il n'est pas nécessaire de fournir ici des sommaires dans les deux langues officielles à moins que le document soit bilingue.)

(U) The Department of National Defence is implementing Capability-Based Planning as a core element in the overall business process. In this context, the Collaborative Capability Definition, Engineering, and Management (CapDEM) Technology Demonstration Project examines the Collaborative Engineering concept to create a systematic link between the conceptualization of a capability and the detailed definition, engineering and management of the component systems. The current report summarises the initial work conducted, from April 2003 to December 2003, by the CapDEM team responsible to work out the Capability Engineering Process (CEP). It describes the main findings about scoping and applying the future Canadian CEP.

14. MOTS-CLÉS, DESCRIPTEURS OU RENSEIGNEMENTS SPÉCIAUX (Expressions ou mots significatifs du point de vue technique, qui caractérisent un document et peuvent aider à le cataloguer. Il faut choisir des termes qui n'exigent pas de cote de sécurité. Des renseignements tels que le modèle de l'équipement, la marque de fabrique, le nom de code du projet militaire, la situation géographique, peuvent servir de mots-clés. Si possible, on doit choisir des mots-clés d'un thésaurus, par exemple le "Thesaurus of Engineering and Scientific Terms (TESTS)". Nommer ce thésaurus. Si l'on ne peut pas trouver de termes non classifiés, il faut indiquer la classification de chaque terme comme on le fait avec le titre.)

Acquisition Process

Capability

Capability Engineering

Capability Engineering Process

CapDEM

SANS CLASSIFICATION

COTE DE SÉCURITÉ DE LA FORMULE
(plus haut niveau du titre, du résumé ou des mots-clefs)

Defence R&D Canada

Canada's leader in defence
and national security R&D

R & D pour la défense Canada

Chef de file au Canada en R & D
pour la défense et la sécurité nationale



WWW.drdc-rddc.gc.ca