Capability Engineering - Transforming Defence Acquisition in Canada

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ABSTRACT

Capability engineering, a new methodology with the potential to transform defence planning and acquisition, is described. The impact of capability engineering on existing defence business processes and organizations is being explored in Canada during the course of a four-year Technology Demonstration Project called Collaborative Capability Definition, Engineering and Management (CapDEM). Having completed the first of three experimentation spirals within this project, a high-level capability engineering process model has been defined. The process begins by mapping strategic defence guidance onto defence capabilities, using architectural models that articulate the people, process and materiel requirements of each capability when viewed as a system-of-systems. For a selected capability, metrics are rigorously applied to these models to assess their ability to deliver the military capability outcomes required by a set of predefined tasks and force planning scenarios. By programming the modification of these tasks and planning scenarios over time according to evolving capability objectives, quantifiable capability gaps are identified, that in turn drive the process towards options to close these gaps. The implementation plan for these options constitutes a *capability evolution roadmap* to support defence-investment decisions. Capability engineering is viewed as an essential enabler to meeting the objective of improved *capability management*, subsuming the functions of capability generation, sustainment and employment.

Keywords: capability engineering, capability management, capability metrics, architecture, model, system-of-systems, systems engineering, CapDEM.

1. INTRODUCTION

Many nations' defence force development and resource management systems, while comprehensive in their subscription to the principles of modern project management, are generally recognized as requiring substantial change if they are to deliver the transformed defence capabilities touted as essential to success on the modern battlefield. It is not uncommon today for threats to national security to change rapidly, with doctrinal and technological innovation far outpacing the defence acquisition systems' ability to respond. Current defence resource management systems typically employ a waterfall process, with substantial upfront effort in defining and documenting requirements to be passed to industry suppliers. As a result, contract specifications are often out of date by the time of contract award. Defence acquisition projects frequently experience schedule and budget overruns as the contractor team tries to grapple with implementation of evolving specifications. The requirement to improve the agility and responsiveness of current platform-centric acquisition processes is exacerbated by the emergence of new war fighting concepts underpinned by network-enabled capabilities. Whether it is the digitized battlefield, network centric warfare, effects based operations, global information grid or a number of other network-enabled concepts – there is the growing expectation for defence acquisition processes to deliver and evolve system-of-systems capabilities with acceptable performance over extended timeframes. The agile, evolutionary defence acquisition process, able to accommodate the step-wise implementation of complex networked systems, is therefore essential to success in modern warfare. Ironically then, transformation[†] of defence forces must begin with a transformed approach to planning and generating defence capabilities that is able to address the complexities of the emerging warfare paradigm.

In the late 1990's, Canada's Department of National Defence commenced implementing strategic capability-based planning to inform its force development process. This effort, led by Canada's Vice Chief of Defence Staff, has endeavoured to break the cycle of replacing the aging or deficient equipment that contributes to a capability with updated

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† J. McCallum, former Minister of National Defence in the 2003-2004 Report on Plan and Priorities, defines transformation as: "a process of strategic re-orientation in response to changed circumstances, designed to make substantial changes in the nation's armed forces to ensure their continued effectiveness and relevance".

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versions of the same platform or system solution. Any defence capability (such as networked fires, close-air support or ISTAR[‡]) consists of people, process and materiel. Hence the goal has been to consider each capability more holistically, wherein alternate solutions are identified to address synergistically the people, process and materiel requirements. Capability based planning leads to a Strategic Capability Investment Plan by considering the current gaps in delivering or supporting capabilities as described in the Canadian Joint Task List. By testing current and proposed future capabilities against various Force Planning Scenarios, desired end states are identified and selected. A key enabler for realizing the capability plan is the process of Concept Development and Experimentation (CDE) now being pursued by most western militaries and NATO, by which future capabilities are postulated and rigorously tested against plausible modelled scenarios. While the capability plan leads to desired capability end states, it does not, however, provide the necessary rigor to define *how* to actually acquire and/or evolve the capability, taking account of the myriad of adjustments to legacy and new systems, and to doctrinal, training and force structures that must be managed synergistically. This paper will briefly examine some of the issues associated with capability engineering, and the methodology being posited for designing and acquiring the capability objectives set out by the capability plan.

2. THE CAPABILITY PARADIGM

2.1. Capability Management.

In recognition of the increasing complexity of military operations and the recognized need to transform to succeed on the battlefield, nations have moved to the consideration of capabilities as the essential building blocks in improved planning for future forces. While originally conceived in the context of force planning, the use of capabilities has since expanded to include all aspects of defence planning and operations.

In this context, *capability management* can be defined as the management of capability through an integrating framework across the inter-dependent functions of generation, sustainment and readiness, and employment (figure 1). *Capability generation* refers to the conceptualization of new capabilities, through the development, planning, acquisition, and life cycle management of the people, process and materiel that comprise the capability. The time horizon of interest runs from the present out some 10-15 years and beyond. *Capability sustainment and readiness* refer to the sustainment of the capability at the appropriate state of readiness, typically on a time horizon from the present out some 5 years or so. *Capability employment* refers to the planning for, and conduct of military operations using the capability. The focus is on the present.

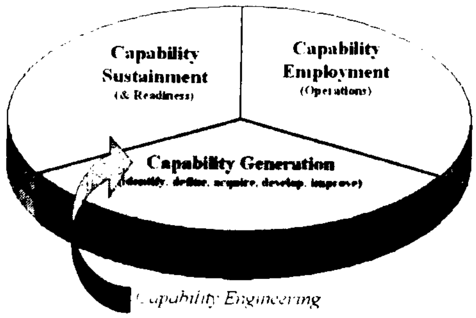

Figure 1. Capability Management consists of three distinct but closely inter-related functions. The capability engineering concept applies a process that will support primarily (but not exclusively) the capability generation function. It is implemented through a combination of an integrated project team, a system-of-systems engineering process, and a collaborative engineering environment, (i.e. people, process & tools).

Historically, defence organizations have assigned responsibility for the capability management functions along organizational or service lines to varying degrees depending, in particular, on the nation's force employment and jointness models. However, this decomposition is problematic when attempting to address capabilities that comprise inherently joint systems-of-systems. Defence organizations are exploring new procedural, organizational and accountability approaches to provide greater coherence and effectiveness across these three functions. For example, one organizational innovation being considered is that of the "Capability Manager", whose responsibilities could potentially span all three functions of Figure 1, although efforts to date have focused primarily on the role in managing the capability generation function. Such a manager would have the authority and necessary level of influence required to manage a system-of-systems portfolio that contains systems that have traditionally belonged within the services. This

[‡] Intelligence, Surveillance, Target Acquisition and Reconnaisance

concept is certainly not unique; good evidence of similar thinking can be seen in the recent Australian Kinnaird Report[1], and a series of essays[2],[§] produced by the UK MoD. Depending on the extent of the CM role, the organizational and accountability impact can be substantial; as such the clear articulation of the value added will be necessary if such an approach is to gain acceptance.

For purposes of this paper and at this early stage of our exploration of these concepts we will focus on the capability generation function. Figure 2 highlights a number of the challenges in managing capability generation. It is clear that an

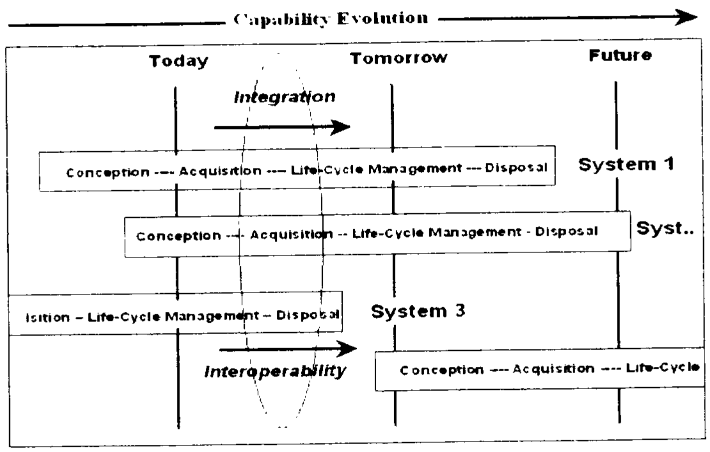

Figure 2. Conceptual illustration of the context for capability engineering. Each system in the portfolio of systems that support the capability may "belong to" various services, agencies etc. Capability engineering must provide the ability to quantify the current capability as a system-of-systems, to project future shortfalls that will occur as a result of system lifecycle expiration for example, and to schedule the corrective action in advance.

evolutionary process is key – capabilities are rarely created at a single moment, but evolve over time. As the capability evolves with time, the constituent systems evolve through their life cycle at different rates. Systems integration and interoperability must evolve in concert with the evolution of the system-of-systems. As problematic for many nations is the reality that the constituent systems comprising a fielded capability in actual operations will be provided by various coalition partners. Therefore, capability engineering must contribute to the ability of trusted allies to collaborate in the development of integrated and interoperable solutions[**].

In Canada, substantial progress has been achieved by strategic defence planners in laying the foundation for capability based planning as a critical step towards the improved management of capability generation. Capability based planning was first introduced in Canada in the late 1990's and has included the institutionalization of Joint Capability Action Teams (JCATs) with concomitant oversight structured around five broad *functional concept* capability areas[††] guided by a Strategic Operating Concept. However, while JCATs are empowered to address the requirements of future forces, it is recognized that this process in itself lacks sufficient rigor – *sic* a capability engineering process - to define, engineer and field (enhancements to) the inherently joint systems-of-systems that these capabilities comprise. Without such a process, the acquisition system inevitably tends to focus on incremental capability acquisition through platform- or system-centric programs driven by individual service needs (Figure 3).

2.2. Collaborative capability definition engineering and management (CapDEM).

During the next few years, attention will turn towards defining and validating a capability engineering process that can better enable implementation of capability plans, as an important step towards improved capability management. This is the prime focus of a Technology Demonstration Project initiated in Canada called *Collaborative Capability Definition*

[§] Essay 6 of this reference focuses on Defence Management and its role in Military Capability Enhancement – a key element identified here is the necessity for a high-level process and a "single Process Owner". Moreover, the report argues for a Business Process Model that is aligned with the outcome of "success in military tasks". The report builds on the UK model of Capability Managers responsible for Equipment areas and suggests a migration to broader applicability including resource and budget alignment.

[**] The capability engineering methodology may ultimately be able to be extended to support the planning for capability employment for coalition operations.

[††] From *Strategic Operating Concept (COP) Working Draft Feb 2004, Department* of National Defence discusses the idea of the *Functional Concepts*: Conduct Ops, Generate, C4ISR, and Sustainment. Each of these is associated with a Joint Capability Assessment Team.

Engineering and Management (CapDEM). The mission of CapDEM is to demonstrate and validate a process that would provide decision-makers with the ability to incrementally evolve operational capabilities more quickly while improving their integration at an enterprise system-of-systems level. This *capability engineering process* (figure 3)

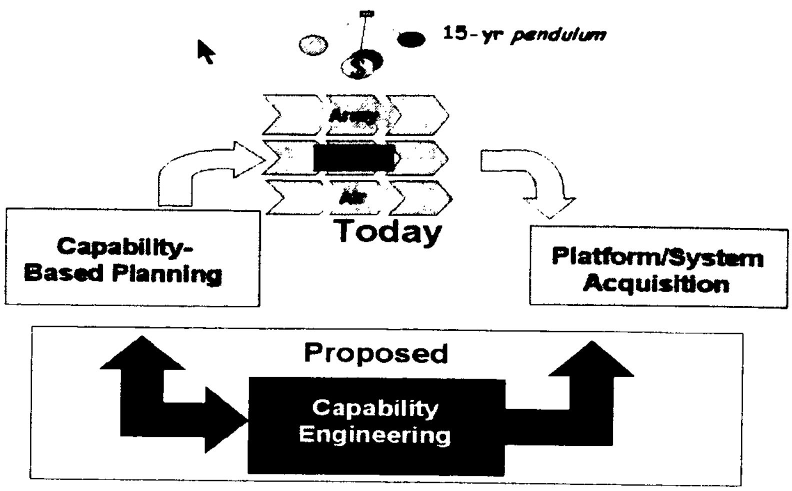

Figure 3. The proposed capability engineering process aims to improve the overall capability generation process by enhancing the link between planning objectives for a specific capability and component service platform- or system-centric acquisition projects, including all related people and process requirements. The pendulum denotes the observation that today cyclic "boom-or-bust" funding often occurs, which can be mitigated by an evolutionary capability engineering approach.

must provide the implementation process that links the nascent *capability based planning* construct to acquisition activities that incrementally deliver changes to our existing capability architecture so that an overall capability area can be managed as a portfolio of a system-of-systems. The goals or expected impact of this process are to:

a) Facilitate strategic agility in capability based planning. The capability engineering process must be able to respond to a rapidly changing environment with more frequent adjustments to strategic objectives than we have traditionally seen, for example by identifying practical changes to the capability evolution roadmap that deliver the new strategic intention as rapidly as possible. The ability to support a reduced timescale for strategic planning and for the fielding of appropriately modified capabilities will enhance agility of the overall planning process.

b) Support Integrated Project Teams (IPTs), potentially spanning allied nations, responsible for capability generation via a distributed collaborative system-of-systems engineering methodology. The methodology decomposes a capability via an architectural framework into models that represent people, process and materiel and can be shared through on-line repositories that enable future capabilities to be designed using knowledge gained from the past. Such a system-of-systems approach is critical to realizing network-enabled concepts that are key to transformation.

c) Transform the current service driven platform-centric defence acquisition process into a capability-managed construct. It is envisaged to use an iterative process to evolve a system-of-systems architecture that begins with the as-is capability, and then rigorously identifies and presents options to decision-makers for augmenting the capability towards a desired to-be end state.

3. CHALLENGES IN CAPABILITY GENERATION

From a systems engineering perspective, it is useful to examine the various constructs that comprise the "as-is" process framework typically found in force development and defence resource management. Our observations of the Canadian situation reveals the following constraints and problem areas, which are indicative of the situation generally found in many nations.

3.1. System-of-systems integration.

While full interoperability of a capability across the services and with closest allies has always been the desired goal, Canada's extensive participation in coalition operations has resulted in the current situation where the nation's Army, Navy and Air Force are often better integrated functionally (combined operations) with their coalition counterparts than they are with each other (joint operations). Notwithstanding the value and importance of combined operations, the continued desire to achieve inter-service interoperability (jointness) requires the desire and ability to apply enterprise level processes within the current defence management environment so as to address the integration issues that need to be resolved. For a variety of reasons, not the least of which is cultural, this level of integration remains difficult to realize for most nations. The common practice is to acquire a platform or system and then address integration with the other stovepipes as needs arise. While this approach has been manageable in the past, the transformational increase in network centricity that is just over the horizon will render this approach dysfunctional. The extent of integration required for the network-enabled concepts of the future can only be achieved through a comprehensive system-of-systems engineering approach that addresses the interfaces from the start. Good evidence of this problem is the pressing need for information and intelligence fusion across the services of most nations. If the existing acquisition processes had been effective, one would expect joint interoperability across the services to be well in hand. The reality is quite the opposite, with many stove-piped C4ISR capabilities going into service in relatively recent years without the extent of integration that is needed to achieve desired joint force capabilities.

3.2. Corporate common operating picture (*corporate COP*).

The common operating picture (COP) is central to situational awareness and decision-making in military operations. Similarly, a corporate COP should be central to situational awareness and decision-making in the context of supporting defence acquisition decisions. Without a common view of the 'as is' and 'to be' problem space for a specific capability area, defence acquisition are at risk of being disconnected and potentially working at cross-purposes. A corporate COP that is based on linked and rigorous analysis provides a more reliable and common foundation through which capability generation can be managed. One approach at achieving jointness being applied by Canada and other nations is to mandate that a jointness review board approve all new projects[*]. Such a joint capability review board examines criteria such as a project's alignment with a strategic capability investment plan before passing decisions on funding. Other program review boards consider more programmatic issues with the project, such as funding and implementation schedules. While some basic methods and tools are currently in place to support and link these decisions, they lack the rigor and content needed to do this very complex and difficult task. Exploring how a corporate COP can support capability management was a key challenge tasked to the CapDEM project in Canada[‡‡].

3.3. Process agility.

It is widely accepted by defence stakeholders that current acquisition processes are in dire need of reform to address their lack of agility. The traditional decade long waterfall process (figure 4) for acquisition has become a limiting factor to achieving transformation objectives. In Canada, the materiel acquisition community is addressing this requirement through a number of initiatives that aim at reducing the overall timeline for individual projects by at least 30%. Analyses conducted over the past few years have revealed that the average duration of a capital acquisition program from concept to fielding in Canada is approximately 15 years[3]. Other western nations also require upwards of a decade to transit similar waterfall[§§4] acquisition processes. While for many projects this prolonged process is affected by political and budgetary pressures, there exists the paradox that the longer an acquisition project takes to deliver, the more vulnerable it becomes to pressures which further exacerbate the timeline, such as requirements creep (often technology and threat driven), cost inflation, budget instability, and even the election of new governments. So how agile must a process become to avoid this effect? Over the past two decades we have witnessed an unprecedented acceleration in the rate of change in political, technological and global threat-based influences on defence. Threats that directly affect national security are now changing at a rate that is measured in months, technology in the information sector is spiralling at a cycle where significant changes occur in the order of 1-2 years. Couple this reality with the poor track record all nations have had with forecasting military requirements further out than 3-5 years and it is obvious that a more agile defence acquisition process has become a necessity.

3.4. Funding models.

If one examines further the way that most defence acquisition processes operate, the tendency is for funding to be injected over a time envelope that is relatively short and very much a step function, possibly over two or three implementation cycles. This funding model is, in large measure, an artefact of a platform-centric acquisition process, which tends to replace ships with ships and tanks with tanks. As we move towards the goal of capability-based management we must explore funding models that provide stable longer-term *capability funding* budgets. Short high-

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[*] In Canada this is called the Joint Capability Review Board (JCRB). The US has the Joint Requirements Oversight Council (JROC).
[‡‡] JCRB Minutes, Department of National Defence Canada, 17 Jan 2003.
[§§] A *waterfall* process for project management is a linear series of activities and is common to most traditional (pre cold-war) defence acquisition processes.

intensity bursts of funding to augment capability deficiencies are not as consistent with a spiral development approach that, while protracted, provides frequent incremental delivery of capability and periodic technology refresh programmed

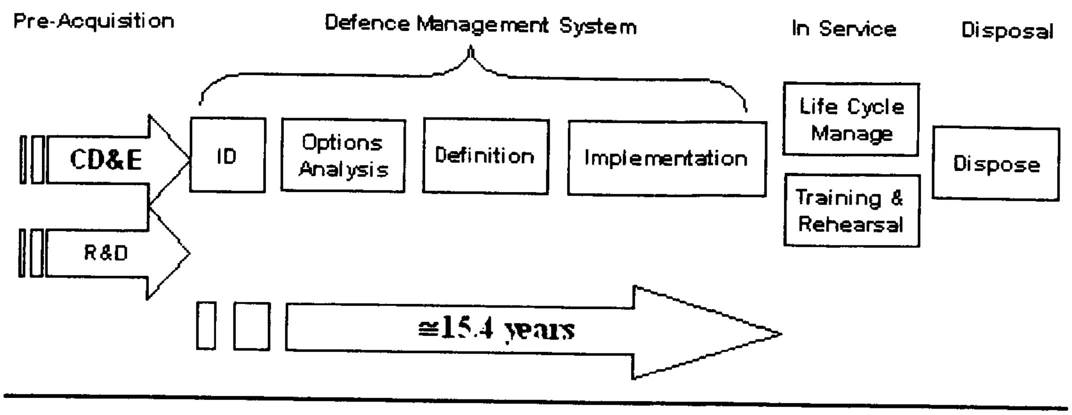


Figure 4. Canadian defence management system is based on a waterfall acquisition process. The typical duration from concept to fielding for large procurement projects has been ~15 years[3].

into the plan at the very beginning. In Canada, we find that the competition between the three services for their share of the defence budget has naturally coupled to platform-centric demands for major acquisition or refitting. The result is the emergence of a pendulum-funding[5] paradigm. Figure 5 conveys this paradigm by illustrating that as each service develops programs to meet their defined goals, via service generated strategic visions*, they inevitably compete for primacy and approval. If one takes the pendulum analogy further, velocity may be visualized as being influenced by the broad departmental investments in, and requisite prioritization of, various service proposals. The path of the pendulum is perhaps most influenced by external forces (e.g., global security environment, technological changes, etc.).

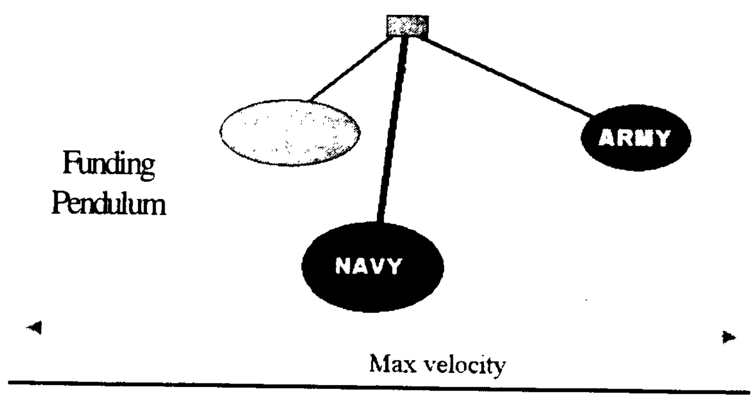


Figure 5. The funding pendulum concept is a consequence of defence budget constraints and environment-driven acquisition programs.

3.5. Defence planning & management (DP&M) processes.

Within Canada's department of national defence, there are six planning and management domains that represent strategic level components of the departmental DP&M framework; they are defined as shown in the figure below.

* As an illustration of environmental strategic visions – the Canadian Navy produced "Leadmark", the Army "Advancing with Purpose" and the Air Force is developing "Vectors…" – the degree of synchronization and commonality of goals between these documents has not been formally reviewed for this paper;

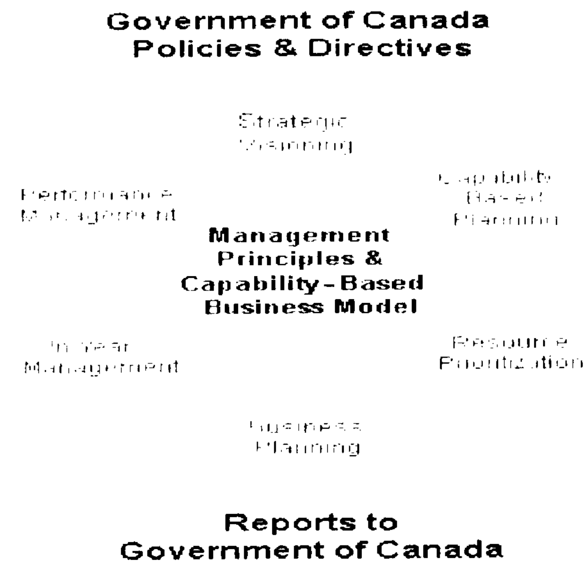


Figure 6. Canadian defence planning and management processes.

As each domain was originally developed to meet specific requirements, they are presently not necessarily well integrated; a recent initiative is investigating the inter-relationships and opportunities for harmonization of these domains. While it is not the intent of this paper to describe in detail the elements of that work, a few of the issues serve to highlight some of the challenges presented to departmental decision-makers; these, are considered to be similar to the situation faced by our allies:

(a) Varying timelines – strategic planning operates on longer term views (10-20 years) whereas business planning functions over much shorter windows (e.g., 12-24 months);

(b) Cross-domain linkages – strategic planning and capability based planning, while reasonably aligned, do not translate well into Performance Measurement processes and tools (e.g., Balanced Score Card); at least part of this challenge lies in identifying relevant metrics.

(c) Resource Prioritization – resource prioritization is challenged by insufficiency in "costing" capabilities (hence the link to capability based planning is tenuous); therefore the focus tends to be predominantly on near term goals to drive resource decisions; and

(d) Insufficient rigor – rigour is lacking primarily in the determination of existing and projected capability gaps as part of the capability based planning domain; however, rigorous capability engineering-like approaches could substantially assist the other DP&M domains as well.

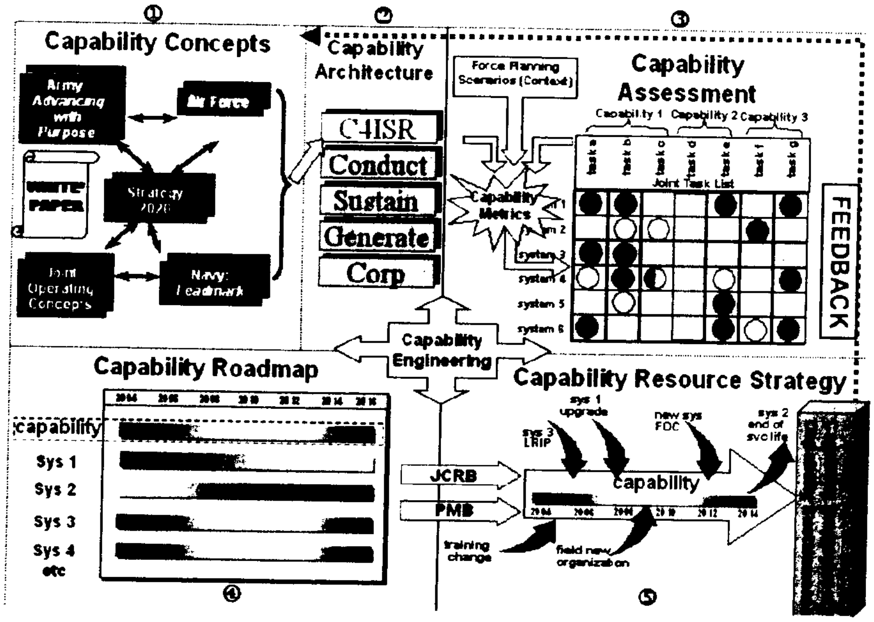
Ultimately, the DP&M domains, in isolation, meet the intended requirement to varying degrees in the "as is" form. However, a holistic view of DP&M, from a strategic vision that is aligned to various planning and management processes is still needed. If we take the military capabilities as the centerpiece of this domain, articulated by "as is" architectures, and evolved towards "to be" through a resource prioritization process that allocates funds through a program of new projects, staffing actions, materiel acquisitions, modifications to tactics and doctrine, decommissioning of assets (cradle to grave approach) and so on, then we will be in a position where we can address the people, process and materiel requirements of the overall capability. While it is not the intent of this paper to suggest *capability engineering* will solve all of the challenges of DP&M, it is important that this front end of the process be well understood and interfaced with any capability management processes that are required to implement activity to fulfil strategic visions. In Canada, the CapDEM project has been challenged with demonstrating an acquisition process that links capability based planning to the acquisition of component systems[6].

4. CAPABILITY GENERATION "TO BE"

4.1 Capability engineering defined

Let us consider a vision for the future where capability generation is fully supported by a robust capability engineering process that implements capability plans. Figure 7 (below) is useful for conceptualizing the overall concept of capability engineering.

Figure 7***. High-level illustration of the capability engineering process (1-5) as it supports capability generation. Note that the process does not deal with trade-offs among capabilities. For example in this illustration, the C4ISR capability would be the subject of the capability engineering process which identifies, defines, and evolves this one capability.



Starting in the top left panel, capability based plans, military strategic and governmental directives are used to map out and validate requirements within a capability model using an architecture framework. An architecture framework standardizes a series of views that express operational, technical and systems perspectives of the system-of-systems comprising the capability. Obtaining a *validated* 'as-is' model of a capability is a critical first step to obtaining stakeholder acceptance of the analysis that follows. Empowered with a validated architecture, capability metrics are applied to assess the gap between the as-is and to-be capability by testing the architecture against a set of postulated future military tasks and force planning scenarios (both of which must also be validated as representative by the stakeholders affected). National capability attributes or characteristics are extracted using some form of standard framework (PRICIE[†††] for Canada, DOTMLPF for the US). The results are represented in a condensed visual fashion (top right panel) for purposes of this explanation, however in reality this analysis has a much more comprehensive foundation.

Using an iterative system-of-systems engineering process with linked analyses, the capability manager supported by the *corporate COP* is in a position to substantiate requests for funding to modify people/process/materiel associated with any system in his portfolio. Judicious scheduling of these changes to the capability over a 5-10 year or longer timeframe generates a *capability roadmap.* The implementation of the approved *capability resourcing strategy* provides all of the activities, acquisitions, organizational/doctrinal changes, technology insertion, retraining and so on that actually results in the augmentation of people, processes and materiel. Decision-makers are supported by this COP and can approve or deny funding based on risk and other forms of analysis conducted within the same environment. . The ultimate goal is to implement an agile, traceable, capability resourcing process that directs the delivery of the required capability. While the above slide depicts the entire capability generation component of capability management, elements of this process

*** Modified from the US Joint Capabilities Integration and Development System (JCIDS), presented by Dr. R. Staats at Institute for Defense and Government Advancement (IDGA) Seminar-- Capabilities-Based Requirements & Architecture Framework – Washington, D.C. – 9, 10 Dec 03.

††† PRICIE is the Canadian capability attribute list (Personnel, Research, Infrastructure & Organization; Concepts, Doctrine & Collective Training; IT Infrastructure; Equipment, Supplies and Services); US apply DOTMLPF for Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities.

also support capability sustainment and readiness. The capability management domains of *sustainment* and *employment* at the bottom right have not been explored in detail in this paper but ultimately would need to be well integrated to the capability generation domain depicted in the above illustration.

This approach applies classical systems engineering principles and methods[7], and is very much based on similar capability engineering processes being developed and applied in other countries (see US JCIDS, USN ChEng Capability Engineering, and Australia Kinnaird Report[‡‡‡]). We contend that application of these processes at a system-of-systems level and across the environmental capability areas within the Canadian Forces will transform how we manage defence acquisition.

4.2. Capability engineering summarized

In a simpler explanation as a summary, capability engineering can be described as containing the following four activities:

4.2.1. Capture as-is capability. Understand, model (depict) and get stakeholder validation on what we have in place today that is expected to provide the mandated military capabilities;

4.2.2. Define options for a to-be capability. Model the options for a "to-be" architecture that show promise for achieving desired capability targets, as derived for example from Concept Development and Experimentation; and

4.2.3. Engineer closure of the gap. Armed with the above, the capability manager applies risk and options analysis to generate an evolutionary acquisition program for implementing selected changes to the as-is architecture so that it measurably changes towards a desired future state. Capability sustainment and employment domains must provide timely feedback to this capability generation domain so that modifications to metrics and architectures can be applied to achieve the desired output.

4.2.4. Capability Evolution. The whole process is iterative and on-going. As new strategic directives are inserted into the capability based planning domain (top left panel of figure above), the concomitant changes to capability architectures will be driven as a result of changes that must be made to the joint task lists, force planning scenarios, and capability metrics that are used to assess as-is and to-be capabilities.

4.3 CapDEM tenets.

As mentioned earlier Canada has committed to exploring the capability generation element of capability management through a technology project called CapDEM. While relatively early[8] in the exploration of the process, the CapDEM Project has identified a number of key tenets for capability engineering:

4.3.1 Model-driven architectures. This tenet states that the key to enabling the improvement of existing capabilities is through the use of architectural models that have clear, traceable links to high level strategic and defence policy authorities. A powerful though not immediately obvious benefit from this enabler is revealed when mapping out the working relationships between organizations or systems, as it articulates their stove-piped and possibly competitive or duplicative nature. Functional analysis, one keystone element of the systems engineering process, greatly simplifies our understanding of the process before we overlay legacy organizational constructs that often obscure the underlying functions that relate to the desired capability. Once validated, a functional process model can be used to build architectures that capture the complexities of legacy and future defence functions. This approach can be a very powerful means for soliciting agreement on solutions that can reduce redundant, duplicative, and bottlenecked legacy functions. Furthermore, it is observed that validation of architectural models becomes simpler to achieve when the appropriate organizations take ownership of their architectural models.

Model-driven architectures lead to convergent architectures in which system services are aligned with capability objectives and defence functions. When target operational architectures and system architectures are subsequently

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‡‡‡ The Kinnaird report[1], while focused on Defence procurement within the Australian Defence Force (ADF) provides a number of recommendations that suggest a broad applicability to redefining and assessing military capabilities. Perhaps among the most immediately noteworthy issues is the requirement for a single focal point for a capability area that is vested with both responsibility and authority to deliver that capability to the ADF. Additionally, this report recommends sweeping changes to the Australian Defence procurement organization both in terms of process and governance.

defined, it greatly facilitates our ability to articulate the capability problem space and thereby capitalize on innovation from across government and industry.

Model-driven architectures enable us to do three important things effectively:

a) communicate clearly and obtain consensus amongst stakeholders on what is the as-is architecture, using standardized language and notation;
b) expose opportunities for improvement within a complex system-of-systems; and
c) manage change with greater confidence through validated executable models.

Hence the first tenet can be paraphrased[9] as *top-down architecture enables bottom-up innovation.*

4.3.2 Iterative System-of-Systems Engineering (Process) Based on lessons learned to date, we believe that the detailed systems engineering process to enable capability engineering must be an evolutionary spiral process that engages the capability engineering team simultaneously in requirements definition and analysis, functional analysis, and design synthesis. The virtues of an evolutionary process are well known and fit well with the overall capability engineering methodology (figure 8). This approach is modeled after MIL-STD 499B which subsequently evolved into IEEE1220.

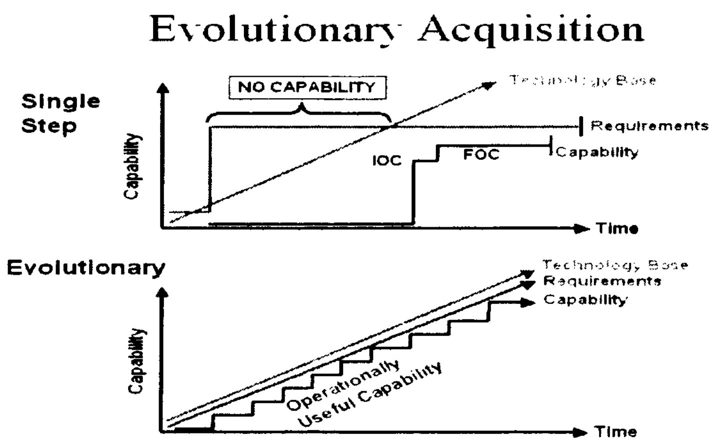

Figure 8. Evolutionary acquisition is well suited to capability engineering.

The key tenet underlying these processes is that we do not wait for requirements to be completely defined before exploring functional analysis and design loops – all three must be performed iteratively and in parallel through linked engineering analyses. Application of IEEE1220 with a suitable architecture framework (DODAF or BOSTIS)[§§§] constitutes the core of the methodology supporting the capability engineering process. Attention to maintaining frequent model synchronization across the key trade study areas such as human factors, whole-life cost, and network analysis, can greatly improve the delivery time for acquisition by avoiding divergence of modeling efforts.

4.3.3. Collaborative capability engineering environment (Materiel/tools). A collaborative on-line environment consisting of integrated systems engineering tools such as are listed below, linked through a common model-synchronization repository is required to support the process:

a) Executable functional analysis modeling tool;
b) Requirements modeling tool;
c) Information Systems modeling tool;
d) Human Systems modeling tools;
e) Program and system costing tools;
f) Programmatic and Risk Analysis tools;
g) Configuration Management tool;

[§§§] While the Department of Defence Architecture Framework (DoDAF) is being used initially by CapDEM because of it's maturity; there is potential that the Business, Operational, System, Technical, Information, Security (BOSTIS) architecture framework may eventually become the mandated departmental standard in Canada.

h) Central repository and data exchange environment that can enable model synchronization/sharing, model change notification, and visualization by modelling team and senior management;

i) Collaborative engineering environment laboratory and tool suite to enable virtual work teams; and

j) Integrated synthetic environment;

4.3.4 Functional integrated capability engineering teams (People). People build systems. Checklists, models, and frameworks do not. Capability engineering delivers a structured methodology and environment that brings stakeholders together to define and achieve critical capabilities in an adaptive manner based on sound information and knowledge management principles. It is important for operators to take ownership of their business processes and to express their operational concepts in terms of operational models and operational architectures. Therefore as a bare minimum, integrated capability engineering teams must incorporate the prime stakeholder/operators in the team to have any hope of success.

Integrated project teams (IPTs) have been around for a long time but it is questionable how effective they are in a government environment where personnel resources are often limited. The problem may not be one of process but of application. Personnel resource constraints make the matrix-assignment approach to manning IPTs ineffective. Technology, policy, and process are areas that CapDEM[10] is exploring in the context of demonstrating how functional IPTs could work to support capability engineering. We believe a new construct for IPTs, potentially called "integrated capability teams" will need to be implemented in parallel with capability engineering. Too often we focus on the process and materiel components of a capability without considering the people element that turns capacity into capability.

Capability engineering will by definition need to bridge across a very wide portfolio of organizations, many of which will be resistant to an organization that may impose new and external constraints. Clearly the challenges to capability engineering will be cultural as well as technical and procedural. It follows therefore, that effective and integrated capability teams are a key to success.

4.3.5 Early Industry Engagement Integral to the IPT construct is the increased involvement with industry at a much earlier than traditional stage. The objective for industry engagement should be to do so as early as possible, as integrated as permissible´, and for as long throughout the lifecycle as practical. Enablers for this tenet include Integrated Project Teams, use of modeling and simulation, and application of model driven architectures as a means for articulating capability gaps.

5. CONCLUSIONS ON WAY AHEAD

Capability engineering, a new methodology with the potential to support defence planning and acquisition holds promise of providing at least a partial answer to the challenges of defence transformation. Since it is still relatively early in our exploration of the concept, it is somewhat premature to predict the likely outcome of efforts to institutionalize the methodology. The potential benefits of an institutionalized rigorous capability engineering methodology, when supported by a coherent architecture-based process, can be viewed against anticipated risks. For example, Figure 9 illustrates the inherent risk-benefit relationship associated with an enterprise application. The dotted line depicts the application of capability engineering to the development of progressively complex systems-of-systems; the bottom left is indicative of relatively modest systems, while the upper right is indicative of enterprise-wide capabilities. Intuitively, at the lower left in the graph, the greatest risk for the approach is technical, where the applicability and understanding of the systems engineering tools and processes is most tested. Focusing the capability engineering rigor at the lower left has the potential to institutionalize bottom-up efficiencies, but does not necessarily support improved enterprise-level decision-making. Alternatively, a focus on the upper right shifts the dominant risk to cultural and organizational issues that greatly increase the collective change that must be successfully managed in order to institutionalize the methodology. In light of the risk-benefit trade-offs, we consider that the optimum target for application of capability engineering is at the level of the Capability Area, for example, C4ISR. As such, the Capability Area would be developed within a common

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Permissibility is defined by legal and contractual regulations which are as yet undetermined – practicality speaks to the nature of the defence industry; however, the objective goal is to achieve long term relationships and thereby support innovation insertion, and the inherent benefits afforded when industry can realistically invest in a "long term" Capability delivery and support.

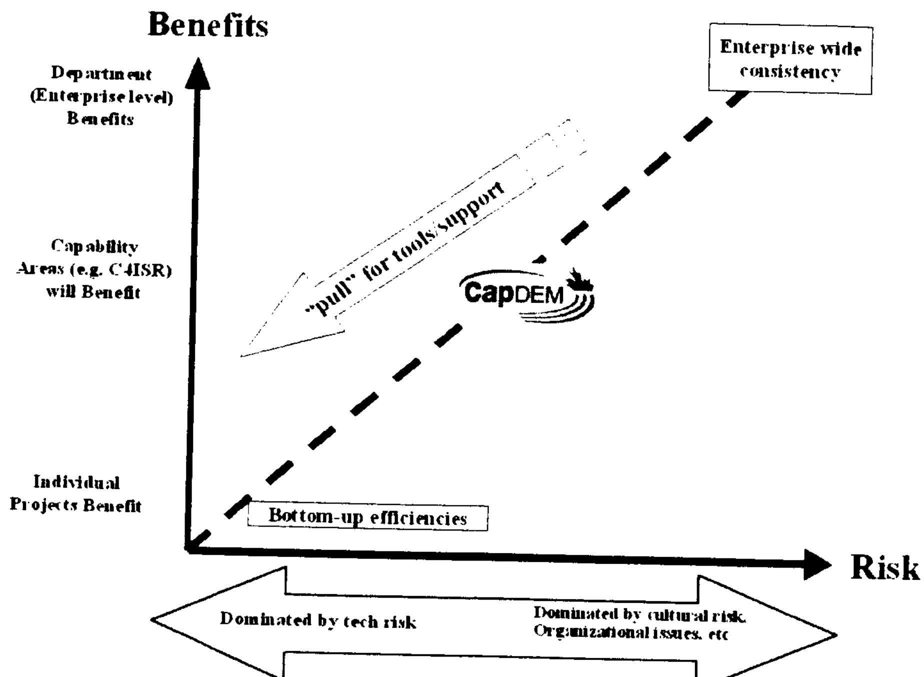

Figure 9. Benefit vs Risk dynamic for institutionalizing the capability engineering construct.

and consistent strategic framework, with a harmonized DP&M, that would be more readily analyzed and resourced. . The mid-point, focused on the Capability Area illustrates a compromise approach and presently serves as the focal point for this risk-benefit dynamic that the CapDEM project team will be using to assess opportunities to institutionalize the methodology over the next two years.

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6. REFERENCES

1 M. Kinnaird, Review Chairman, Defence Procurement Review 2003; prepared for Dr Peter Shergold, Secretary, Department of the Prime Minister and Chair of the Secretaries Task Force on Defence Procurement, Australia.

2 Delivering Security in a Changing World – Supporting Essays, Dec. 2003 (Secretary of State for Defence, UK).

3 Capital Acquisition – Getting it Right in 30% Less Time, Implementation Plan, April 2002. Adm(Mat) DND Canada.

4 S. Doll, Waterfall for new managers http://builder.com.com/ July 24, 2002.

5 C. Pogue, Adapted from "Lance, Transport, Scout and Shield" (in preparation) as presented in *A Conceptual Model of Military Capabilities and an Integrating Functional Architecture to Facilitate Military Capability-based Planning*, Society for Computer Simulation (SCS) Summer Multi-conference, July 2003..

6 Minutes, CapDEM Senior Review Board Meeting, 4 March 2003, Department of National Defence, Canada.

7 For example, Mil Std 499B, and it's subsequent IEEE 1220, and ISO/IEC15288

8 CapDEM Technology Demonstration Project was initiated May 2003. http://www.capdem.forces.gc.ca;

9 L. Cochran, Senior Systems Engineer Consultant to CapDEM, Lansdowne Tech. Ltd., Ottawa Canada.

10 Waruszynski, B.T.; *Enabling Collaborative Capability through Virtual Teamwork: The Way Ahead.* DRDC TM 2003-217

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