Eliciting Modelling and Simulation Capability Requirements: A Naval Case Study

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ABSTRACT

Modelling and simulation (M&S) are enabling technologies that are used by military organizations for a wide variety of purposes. New opportunities, as well as challenges, for the use of this enabling technology arise from advances in M&S and changes in military problems. Understanding this changing landscape is an important element in planning investments in M&S resources. The aim of this paper is to report on a requirements engineering approach implemented to align M&S technology investments within Defence R&D Canada (DRDC) with the Royal Canadian Navy's (RCN's) expected requirements.

A requirements-engineering approach was employed, concentrating on the elicitation and modelling of expected future requirements and current capabilities. Two separate elicitation exercises were undertaken to address these linked information sets; RCN requirements elicitation was accomplished using stakeholder workshops and model-driven surveys, while DRDC capability elicitation was done directly with the technical community. The resulting RCN requirements were modelled in terms of nine high-level Navy capability areas. For the DRDC M&S capability inventory, a taxonomy of M&S capabilities was created, and integrated with simulation performance and expertise measures.

From this undertaking, observations are offered to the M&S Policy, Standards, Management, and Acquisition community regarding effective means of engaging with the breadth of M&S stakeholders in a medium-sized navy, the effective use of different elicitation techniques, and establishing a conceptual framework for M&S capabilities and requirements. Taxonomies and performance metrics developed to support the study are presented as examples of the tools required to progress the understanding and management of M&S capabilities.

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INTRODUCTION

Modelling and simulation (M&S) is part of almost every defence department project and is an important enabler for handling the increasing technological complexity and cost of acquisition, training and operations. In his 2015 guidance to the Canadian Armed Forces, General Lawson as Chief of the Defence Staff (CDS) said "We must continually leverage modelling and simulation to improve planning, increase readiness, and stimulate change" (CDS, 2014). The increasing use of M&S to offset the cost of live exercises and trials, as well as the increasing resources employed for M&S, have caused the Canadian defence enterprise to acknowledge the criticality of M&S to achieving its goals. This realization in turn raises questions about how M&S is managed.

There are two aspects of M&S that affect how it is managed within the defence enterprise. First, M&S is often viewed as a commodity – something that is generally available or as something someone else delivers. Thus, Canadian defence projects have seldom budgeted for the development and maintenance of M&S capabilities. Instead, defence support organizations either provide the M&S capability outright or provide the expertise to allow for contracting from industry. This leads to the second aspect affecting the management of M&S. The majority of the defence department's M&S capability exists as secondary supporting skill sets within the various communities in the defence enterprise, and M&S capabilities have tended to concentrate with scientists, engineers and training support staff. Thus, the Canadian defence enterprise has significant capabilities, but they are spread thinly and relatively few individuals self-identify as M&S specialists. M&S is a tool with which people do their primary jobs. Synthetic Environment Coordination Offices exist, and perform valuable function, but their role is not to manage a capability.

In Canada a large proportion of the government's defence M&S capability is resident within Defence R&D Canada (DRDC), and as the amount of M&S in use within the department has increased, so has the draw upon DRDC's M&S capabilities. The question of whether specific management of M&S, as a capability, is needed has therefore become more pressing. As a result the Director of Science and Technology – Navy (DSTN) sought a better understanding of DRDC's M&S capability, and the Royal Canadian Navy's (RCN's) anticipated requirement for M&S. The Virtual Seas (VSEAS) project was established in 2015 to address this problem by assisting the RCN to identify their ongoing and emerging M&S requirements, and to develop an understanding of how current DRDC program is developing and maintaining M&S capability relevant to those requirements. The intention is that a comparison of current and desired M&S capabilities will allow the identification of where DRDC investment in M&S capability should be focused.

This paper looks at the two main aspects of the problem: how to elicit M&S capability requirements (both current and anticipated) and how to measure the state of existing M&S capabilities. The paper is structured around a requirements engineering process and details a number of information management tools that were developed to provide structure to the implementation and analysis. In the final section lessons (to be) learned are drawn from the process and recommendations for the evolution of the tools are given.

REQUIREMENTS ENGINEERING PROCESS

To understand the RCN's requirements and DRDC's capabilities, the project adopted Nuseibeh and Easterbrook's, (2000) requirements-engineering approach. This approach uses a process of four major steps: determining the context; eliciting data; modelling and analysing the data to extract requirements; and validating the results. The work reported in this paper concentrates on the elicitation and analysis steps where the majority of generalizable results were obtained.

CONTEXT

At the centre of the organizational context for requirements is a military client, the RCN. This sets the problem space to be addressed by M&S - problems of acquisition, force development and generation, and force employment. The organizational context for capability capture is the client's primary M&S technology knowledge provider (DRDC) for whom M&S is mostly a tool to achieve its primary goal of science and technology investigation for the RCN. This describes the capability for this study – providing M&S to meet the RCN goals. As part of this context, it is important to note that DRDC is not the sole M&S technology provider as the RCN also has significant resources available internally (e.g., Naval Engineering Test Establishment), and accessible from industry. Thus, part of the context of this work was to provide information to support DRDC's capability investment program.

The broader organizational context situates the RCN and DRDC within of the purview of the Government of Canada and as members of military alliances and scientific organizations. This context serves to set a number of expectations. The RCN and DRDC work with the world-leaders in maritime operations, defence research, and M&S. They therefore expect that high-quality M&S will be available, either locally or through collaboration. Interoperability is also implied by this context. The RCN works with the rest of the Canadian Armed Forces (CAF), other government departments, and allied forces around the world. It is expected that their M&S should also be similarly interoperable when required. The situation for DRDC is similar. DRDC supports all of the CAF and is organized as a number of technology area laboratories (e.g. radar, optics, sonar, structures, operations research) that are distributed across the nation. Since few of the technology areas are navy specific, the RCN's scientific support program is spread across most of the labs and often a particular research team has projects for both the RCN and other elements of the CAF. In some cases, science and technology (S&T) programs that support the RCN are sponsored by other elements. Thus, most DRDC M&S capabilities are part of the larger infrastructure required to support research rather than existing in, and of themselves, to support RCN current activities. Again, it is expected that DRDC will seek interoperability with allied defence research organizations.

Capability Based Management

A key aspect of the organizational context is the Department of National Defence's recent Science and Technology Strategy (DRDC, 2014). In aligning with this strategy, DRDC is implementing capability based management to better understand and manage its science and technology resources. This drives this study's capability orientation in general. More specifically, the capabilities need to be considered as part of a hierarchy (NATO, 2015) and written as "a stated ability to achieve some objective (do something) within a particular environment (set of constraints)" (Hazen et al., 2002). To satisfy this definition, and within the context described above, the DRDC M&S capability elicitation probed for both level and environment/constraints.

DATA ELICITATION

To capture M&S capability spread geographically, and across scientific disciplines and research programs, it was decided that a combination of surveys and interviews would be required. A team of M&S subject matter experts (SMEs) was recruited, from the major laboratories expected to have significant input, to help design and implement the study. Similarly, M&S requirements arise from across the naval defence enterprise, thus, a combination of

methodologies was employed. Once the M&S requirement and capability elicitation materials were developed the team members were responsible for gathering the data, and a workshop was held to conduct analysis.

The elicitation began by developing a working model of M&S capability. This model was then used to record and organize requirements and capabilities collected from the RCN and DRDC respectively. Elicitation of M&S requirements from the Navy was accomplished in parallel to the capability elicitation, using stakeholder workshops, model-driven surveys, and interviews. Conducting both elicitation processes simultaneously was mostly driven by timing of access to RCN SMEs, and the study timelines. However, one result was to minimize the impact of results from one process overly biasing the other.

The Working Model of M&S Capability

To organize the collection of data, the authors developed a model of a generic M&S capability. The generic M&S capability model is based on the types of tasks that would be required to "do something" using simulation. Table 1 gives the list of model elements and associated tasks starting with the provision of expert advice, moving through having the software available, to the ability to validate and understand the output.

Table 1. Generic M&S Capability Model

Model Element	Simulation Usage Task
Expert Advice	Provision of expert advice to other users of the simulation software
Create/Modify Software	Ability to create new or modify legacy software to fit a task
Software Available	Commercial of the Shelf (COTS) or Government off the shelf (GOTS software is available for use
Knowledgeable User	There are knowledgeable users to configure and run the simulation software.
Valid Input Data Available	Valid input/configuration data is available to allow the simulation to be run for the required purpose
Generate Valid Data	Valid input/configuration data can be generated to allow the simulation to be run for the required purpose
Ability to Validate Data	Input/configuration data provided by another party can be validated for the simulation and required purpose
Validate Output Data	Output data from the simulation can be validated/understood/analysed for the required purpose

A working taxonomy of M&S for naval applications was then developed. The initial approach was to draw upon a military task-based taxonomy such as the Universal Naval Task List (UNTL) (USN, 2007). However, the UNTL is so comprehensive that by the time the level of scientific M&S is reached the number of categories was far too large for use in the study. Further, since many M&S capabilities could support multiple tasks it was unclear if such a categorization would be useful. The second approach considered M&S technical/algorithmic categories and sources such as the US Department of Defense's M&S Catalog (MSCO, 2012), M&S Glossary (MSCO, 2016), and NATO M&S Standards Profile (NATO, 2015). While all provided useful information, none of them gave a taxonomy with a granularity that was practical and useful for the study in question; that is they were either too specific to a part of the problem space, or too general in categories. The third approach looked at taxonomies embodied in the Tables of Content in a number of M&S textbooks such as Tolk, (2014) and Law, (2016). Again, while these sources gave some good ideas they did not fit to the study's problem area at an appropriate granularity.

Taking information from all of the above sources and using the team's personal experience, the taxonomy shown in Table 2 was developed. This taxonomy uses an initial level to break naval M&S into a set of primary technical areas, which are then supplemented by a set of secondary technical areas within the primary. During data collection this taxonomy was further refined, although only a few extra categories were added. Later, following the data elicitation stage of the study, categorization into military warfare areas was added during the data modelling stage.

Table 2. Simulation Technical Taxonomy

Primary Technical Area	Secondary Technical Area	Primary Technical Area	Secondary Technical Area
Combat Engagement modelling	Sensors performance	Process Modelling	Business
	Unit Kinematics		Logistics
	Weapon/Effector Operation		Personnel
	Weapon/Effector Effects		Training
	Scenario Generation		Economics
	Non-belligerent forces		Cultural effects
	Tracking	Environmental	Oceanographic
	Tactics		Atmospheric
Damage Modelling	Wear /Corrosion/stress		Terrain
	Explosive Effects		Weather
	Component damage Likelihood	Information Modelling	Networks
	Structural		Communications
Platform Motions	Naval		Content Structure
	Air	Infrastructure	Interoperability
	Land		Distributed Simulation
Signature/material modelling	Acoustic		VV&A
	Hydro/Aerodynamic		Error estimation
	EO/IR		3D Model Generation
	EM		Training Efficacy
	Strength		Visualization
Mechanical systems	Naval		Network requirements
	Air		Simulation Control
	Land		Scenario Data Content
	Components		Configuration management Tools
Human Systems	Ergonomics		Interface Emulation
	Cognitive		High Performance Computing
	Medical		
	Team Dynamics/Org		

The model given in Table 1 and categorization given in Table 2 provided an overall structure and language for talking to individual M&S practitioners about their capabilities. However, the aim of the study was not just to understand the breadth of DRDC M&S capability, but to also develop an understanding of the health of the capabilities. Three dimensions of health were determined to be important:

1. The strength of the capability in terms of numbers of personnel, knowledge, ability to respond to a request etc.
2. The trajectory of growth of the capability
3. Whether the capability is resident within DRDC or is a combination of DRDC and industry.

Table 3 gives a scale developed for use in the DRDC elicitation process. The scale was used for each of the elements of the generic capability model.

Table 3. Simulation Capability Status

Capability State	Description
None	No program or minimal capability
Weak Developing	Growing capability within an active program
Weak Stable	Some capability with program to maintain
Strong Stable	Significant capability with active program
Strong Waning	Significant capability but minimal or no program to maintain
Weak Waning	Some capability with minimal or no program to maintain
Contracted Developing	Contract mechanism available and increasing capability or developing ability to supervise contract
Contracted Stable	Contract mechanism available and capability being sustained and ability to supervise contract
Contracted Waning	Contract mechanism available but contractor capability declining or ability to supervise contract declining

Eliciting Royal Canadian Navy Simulation Requirements

The RCN requirement elicitation process drew upon RCN M&S subject matter experts attending a meeting of the Maritime Synthetic Environment Working Group (M-SEWG) in November 2015 and upon follow-up meetings with the workshop participants.

The M-SEWG meeting is held annually to bring RCN M&S expertise together for the purpose of coordinating effort. In the case of the November 2015 meeting it also included a workshop to initiate a review of the RCN M&S policy. Attendees to the meeting were informed prior to the meeting that the DRDC team would be using the briefings and interactions as an opportunity for unstructured requirements gathering. The M-SEWG is structured around a series of briefings on the M&S activities underway within the RCN establishment; including Concept Development and Experimentation (CD&E), individual training, distributed mission operations, naval requirements, and major and minor acquisition offices. In addition, there were briefings on army, air force and joint M&S programs. These briefings and question periods were used by the team to individually develop sets of requirements. Further, each of study team members delivered presentations on the naval M&S programs from their lab. The questions and comments from RCN participants formed another important part of the data collection.

After these meetings, the study team followed up by contacting some members of the M-SEWG. These conversations provided opportunities to obtain greater depth of information, to confirm correct understanding of the requirements by the team, and to re-organize information in accordance with the more finely-grained model developed during analysis.

Eliciting DRDC M&S Capabilities

The DRDC portion of the knowledge elicitation was meant to look at the existent capability available within the organization that might be drawn upon by the RCN. Using the above working models the study team canvased their areas of responsibility between September and October 2015. The results were then consolidated in a master spreadsheet of 244 individual M&S capabilities.

Individual team members used a variety of methods to elicit data, ranging from surveying DRDC M&S practitioners via electronic distribution of model with follow-up, to structured and unstructured interviews. Techniques varied according to the perception of how best to encourage participation of individual M&S practitioners. In two labs an initial lab-wide seminar was given as part of the regular seminar schedule to announce the study and familiarize

personnel with the aim and process. In another lab some of the M&S capabilities were able to provide the results of an internal verification and validation process characterizing a number of technical performance metrics.

DATA MODELLING, ANALYSIS AND VALIDATION

Following the initial elicitation of data, the study team analysed the data, revised the model, and solicited additional data during the autumn of 2015.

Initial Difficulties in Capability Data

It had been anticipated that the DRDC capability elicitation would identify a large number of capabilities of varying level and type. However, the greatly varying breadth and depth of the science and application areas identified during the elicitation phase made developing an analytic hierarchy problematic. For example some scientific simulation capabilities have very high detail levels in order to support the particular scientific investigation; the same simulations may also be used to generate inputs for less detailed broader scoped simulations used for higher level studies. For some studies a number of different simulation technologies are used to investigate the same problem; for example the use of different solution methods for the wave equation in environmental modelling. In other instances, a higher level simulation may be used for multiple purposes by different S&T teams, focusing on different parts of an overall problem that the simulation can represent; these might represent different M&S capabilities. Thus, the analysis was constrained to aggregate level constructs of the taxonomy given above, warfare areas and coverage of RCN requirement areas.

Another issue was the differing understanding of the terms model and simulation amongst those surveyed. The study adopted the NATO M&S Standards Profile (2012) definitions:

- Model - A representation of a system, entity, phenomenon, or process. Software models of specific entities are comprised of algorithms and data. A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.
- Simulation - A method for implementing a model over time.

An important distinction that arose during the study was the use of the term “model” for both the process or algorithm, and the specific instantiation that combines the algorithm with data. Both represent significant M&S capabilities, and may require significantly different skill sets and software tools. Nevertheless, the term “model” was acceptable for both instances.

RCN Requirement Data Consolidation

Following the M-SEWG, the study team held a full day workshop to consolidate the captured requirements. This process produced 50 Naval M&S requirements that were given an initial validation by the RCN project sponsors at the end of the workshop. The study team was dissatisfied with this initial model. The team had anticipated that requirements would fit into the same type of capability model and categorization used in the DRDC elicitation. The RCN requirements, however, were at a much higher level of abstraction, with a large proportion being more issues of policy than specific types of M&S. Indeed, the majority of DRDC M&S capabilities were covered by a small set of requirements that called for *authoritative models of all RCN and threat units* and *all RCN combat capabilities*. As a result, there were too many requirements for easy reporting and the DRDC capabilities categories could not be reconciled with types of requirements gathered. Over the next month, a qualitative cluster analysis was conducted by some team members and detailed descriptions of the requirements were developed based upon the team members’ notes and workshop discussions. The result was a smaller number of requirement categories. Table 4 shows the nine high level requirements categories that were developed from the cluster analysis.

Table 4. High-level RCN M&S Requirement Categories

Category	Description
M&S Resources	Specific requirements related to populating and enabling the simulation of Navy systems
Force Development	Requirements for simulations to enable specific investigations of TTP development, crewing, fleet mix and new warfare concepts
Force Employment	Requirements for simulation to enable system operators to optimize the use of naval capabilities, including planning aids.
Acquisition	Requirements to support the development or assessment of acquisition requirements
Force Generation / Training	Requirements for simulation knowledge specific to force generation activities
Hardware / Interfaces	Requirements for policies and processes to facilitate the access, interconnection and distribution of simulation resources. (Networks, repositories, etc.)
Knowledge Management	Requirements for the effective use of departmental simulation data, information, standards
Systems Engineering / Processes	Requirements for departmental policies and procedures for developing and using simulation capabilities

Analysis of the DRDC capability data showed at least three areas where more detail would be useful. Firstly, the linkages and dependencies between capabilities were only loosely captured making it difficult to track capability across organizations. Secondly, the capabilities are biased to DRDC's primary mandate of the investigation and demonstration of military application of new technologies (DRDC, 2014); thus, simulation capabilities related to policy and process are at best implicitly captured. Explicitly looking for knowledge of issues such as the implementation of validation and verification, or use of the Distributed Simulation Engineering and Execution Process (DSEEP) would address this deficiency. Thirdly, the elicitation did not explicitly address capability performance in terms of ability to respond to requests, except implicitly through the capability strength data. The categorization used worked fairly well as a language to talk to scientists and engineers; however, the requirements categories followed a very different structure. Overall there was a good distribution of capability across the technical areas, with heavier concentrations in areas of active research. Detailed analysis of the capability model categories and capability health data is ongoing. An area of potential research is whether the overall health or resiliency of a research area can be characterized by the distribution of developing, stable, and waning capabilities.

Initial requirements capture did not see the expected bias toward short-term drivers, possibly because the requirements were drawn from a population who were engaged at the policy and longer-term strategy level. The later medium level requirements showed more variety with several very specific requirements that are related to current shortfalls. Unfortunately, only 20% of the responses filled out the performance scales so no conclusions can be drawn at this time. This lack of data may indicate that more detailed instructions were required.

Final Requirements Model Development

Subsequently, it was decided to develop a more detailed data model and survey instrument in an attempt to match data granularity between the DRDC capability and RCN requirements data and to gather more detailed sub-requirements. This process would also expose the November data set to a wider validation community. The revision added information on current access, desired access, and desired performance to M&S, based upon the verification and validation criteria developed at DRDC Valcartier Research Centre (Lambert et al., 2016). Table 5 presents the scales used to describe these requirements. The revised model was circulated through the RCN Modelling and Simulation Cell at the Canadian Forces Maritime Warfare Centre (CFMWC) and to M-SEWG participant offices with the request for recipients to validate the included requirements and add more detailed sub-requirements.

Table 5. M&S Requirement Access and Performance Scales

Scale	Current Availability	Desired Availability	Desired Source	Need Level	Level of Detail	Level of Fidelity	Level of Performance
1	None	None	Contracted	Waning	<30%	Sig. Diff	<< Real time
2	> 6 months	> 6 Months	Allies	Ongoing	30-70%	Imp. Diff	< Real time
3	1-6 months	1-6 months	Government	Growing	>70%	Reasonable Diff	~ Real time
4	<1 month	<1 month	Department	Periodic		Small Diff	= Real time
5	<1 day	<1 day	Unit			Neg. Diff	> Real time
6	On demand	On demand	Desktop				>> Real time

The results of this information request were then the subject of a full day workshop in early March 2016. From the results an additional 80 medium level requirements were obtained giving 134 in total, adding considerable detail in many areas. Reviewing the final set of requirements and the M&S capabilities revealed that the two resulting datasets are still too different in level and fidelity for a direct comparison. It was possible, however, to conduct a qualitative coverage analysis of the requirements by DRDC capabilities. Each requirement was assessed for uniqueness and then rated by the team's perception of DRDC capability coverage of the requirement. Of the 134 medium level requirements 104 were assessed as significantly different and therefore rated. Of the 104, seven were completely covered by current capability, 37 were partially covered, and for the remaining 60 DRDC has some expertise in the area. Fully and partially covered requirements were heavily skewed to the M&S Resources and Force Development categories, while the other more policy-oriented categories were generally ones where DRDC can contribute expertise.

Overall qualitative analysis of the RCN M&S requirements showed three ongoing themes: firstly the need for authoritative data to increase trust in the simulation outcomes; secondly, the need for access to subject matter experts from across the defence enterprise; and thirdly, a shift in the type and quantity of M&S capability support required from that which research programs can directly provide.

Finally, the validation of the collected data and model has started but is not complete. The first step in validation occurred at the conclusion of the M-SEWG meeting in November, where the team presented their observations to the M-SEWG members. The resulting feedback was used to revise the model as described in the previous section. The second occurred when the revised data model and follow-up M&S requirements elicitation was conducted in January 2016. The revised model and outputs of the study were also presented to RCN M&S offices and to the Directorate of Naval Requirements (DNR) in the winter of 2016 for their use and to obtain their feedback. The sponsors provided positive feedback in the form of comments. The strongest feedback, use of the results by the sponsors in program planning, has not yet been obtained because their planning process was not complete at the time of writing this report.

LESSONS LEARNED

Overall the RCN requirement elicitation was successful in identifying medium to high level RCN requirements, which, while not authoritative, have been validated at a mid-level staff officer level. However, even the second more detailed set of requirements failed to reach a level that is easy to compare to the DRDC M&S capabilities, or a level of detail that a definitive scientific simulation project could be built around. This may be an indication that the balance of M&S capability provision is changing from primarily science/research program products to a more enterprise/production environment.

The output of the two elicitation processes is a fairly rich set of data that is indicative of the current inventory of M&S capability in DRDC, and the high-medium requirements of the RCN. Analysis of the data was progressed via individual team members and through joint workshops. A major issue has been the difference in level and detail between the two data sets. This was partially addressed by the second requirements process described in the last section; however, a direct gap analysis was not possible due to the remaining granularity miss-match.

From both elicitation exercises, at DRDC and with the RCN stakeholders, the study team was able to draw some lessons learned, presented below:

1. Capturing M&S capabilities and capability requirements would be greatly aided by mature taxonomy. One can be developed but it should not be assumed that it will be readily understood by M&S requirements holders and providers, due to their different perspectives on M&S.
2. Personnel conducting M&S requirements and capability elicitation should use the same structure across organizations. This should include consistent definitions, background information, and survey execution methods. Ideally this will be established in a training session for the team.
3. A pilot trial process would have revealed the deficiencies identified in this report and would have allowed for corrective measures to be implemented.
4. While the DRDC M&S capabilities were captured as science and technology capabilities with varying levels of technical readiness, a different type of capability elicitation is required to identify capabilities in the areas of simulation policy and knowledge management.

While it was expected (and stated up front to participants and sponsors) from the beginning that the study would not be exhaustive, the results are felt to be generally indicative of breadth and type of technical capability. Overall the capability model and capability status tools allowed the DRDC personnel to identify the strengths and weaknesses of their programs; including highlighting areas where staff turnover could significantly impact capability.

CONCLUSION

Modelling and simulation capabilities within defence departments, while becoming ubiquitous and critical to the defence enterprise, remain mostly secondary supporting tools, albeit supporting tools for an increasing range of primary military capabilities. A result of this characteristic of "a little bit everywhere" is that the tools for describing and inventorying M&S capabilities are under-developed. In this paper, a number of initial tools in the form of taxonomies and capability measures have been reported.

The provision of M&S capability in the Canada's Department of National Defence appears to be in a time of change with a transition of M&S technology and knowledge from the research community to the greater enterprise. While the provision of validated models and knowledge of new M&S technology will remain a function of the defence research community, the provision of ongoing production level M&S is likely to need a different structure.

Getting this new balance of research and production level capabilities close to correct will require the development of common language and tools, as well as new processes for interaction. This is particularly true for small defence forces with tight personnel and resource budgets. As the transition and re-balancing of effort evolves it will be important for managers to understand both the capabilities required and the health of the inventory in place.

The tools for M&S capability determination described in this paper are a first iteration in the development of a methodology to assist in this process. As might be expected they will need to evolve. In order to match capability with requirements, the capability inventory tools should be expanded to include dependencies between levels of the hierarchy of capabilities and to capture knowledge relevant to the policy side of the enterprise. Organizations attempting a similar process will want to ensure they have the time for training survey teams and M&S personnel in a common language and understanding of the survey instruments.

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