Role of Effects-based Metrics in Advancing R&D Agility through Modelling and Simulation Based Exercises

C. Pogue
Greenley and Associates Inc
1135 Innovation Drive, Ottawa, ON, Canada

chris.pogue@greenley.ca

A.L. Vallerand, J. Pagotto, and S. Lam
Defence R&D Canada Ottawa
Future Forces Synthetic Environment, Ottawa ON, Canada

andrew.vallerand@drdc-rddc.gc.ca

jack.pagotto@drdc-rddc.gc.ca

sylvia.lam@drdc-rddc.gc.ca

ABSTRACT

While modelling and simulation technologies have been applied across the breadth and depth of military applications, such as concept development and experimentation, system and force structure design, training and operational decision-support, the perceived value of M&S technologies has seemingly focused on traditional measures of cost-effectiveness associated primarily with the consequence of early decisions on downstream lifecycle cost avoidance. The lack of extensive and rigorous side-by-side analysis of the validity of these assertions results in a reliance on anecdotal and subjective evidence which receives operational end-user acceptance when the results are intuitive. Unfortunately, this has yet to fully transform the role of M&S within the decision making process. A series of inter-related, M&S-focused activities within the Future Force Synthetic Environment Section of DRDC Ottawa Laboratory have begun to explore a metrics approach that recasts M&S value in terms of "effects-based" outcomes. This on-going development has shown early potential as both a diagnostic and strategic measurement approach to address how the defence R&D community could increase its agility in response to evolving operational mission requirements through an M&S-based framework. A "utility" metric is described which characterizes preliminary results of both a Live and Synthetic Environment (SE) based trial of a military operational scenario associated with littoral intelligence, surveillance and reconnaissance (ISR). The results highlight operational end-user perspectives on the value of SE-based experimentation and perceived M&S limitations, which prompted the subsequent metrics development to focus on measuring the outcomes of M&S-based analysis within an "effects-based" framework that more closely mirrors operational mission Key Performance Parameters (KPPs). A follow-on SE-based trial, centred on a domestic security scenario and the role of Uninhabited Aerial Vehicles (UAVs) in defined ISR tasks, is currently applying an "effects-based" measurement structure employing operational principles of "Persistence, Agility, Information, Reach, and Range" to evaluate options in terms of the operational impact of various system-of-systems configurations in achieving mission objectives. Additionally,

Pogue, C.; Vallerand, A.L.; Pagotto, J.; Lam, S. (2005) Role of Effects-based Metrics in Advancing R&D Agility through Modelling and Simulation Based Exercises. In *The Effectiveness of Modelling and Simulation – From Anecdotal to Substantive Evidence* (pp. 4-1 – 4-14). Meeting Proceedings RTO-MP-MSG-035, Paper 4. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

these same terms were used as a measurement framework for the value of the M&S-based approach itself in achieving Capability-based system-of-systems decisions. The results of these studies demonstrate that this metrics framework for M&S utility can shift the value focus from cost-effectiveness to decision-support effectiveness.

1.0 INTRODUCTION

"You cannot change the things you cannot measure"

The use of Modelling and Simulation (M&S) is not new to the military operational community and has for many years formed an operator-accepted centrepiece to support military training, operations research and concept development activities. With the emergence of Synthetic Environment based Acquisition (SEBA)[1] the role of M&S has increasingly broadened in response to a period of decreasing defence budgets and seemingly evolved the perception that M&S 'value' existed in a cost benefit framework in which Return of Investment (ROI) shapes the measurement of 'value' and guides associated analysis [1]. In fact, the intuitively accepted state that in all but the "ideal case" acquisition programs employing M&S will have reduced program risk while providing down-stream cost avoidance essentially defines how the operational community views M&S 'value' [2],[3],[4]. It is arguable that while M&S 'value' is comprised of both tangible (quantifiable) and intangible (unquantifiable) benefits there is a tendency to attribute tangible benefits to traditional 'financial-centric' measures such as ROI whereas intangible benefits rely more heavily on anecdotal evidence and application case studies that most frequently affirm existing perceptions. For the operational community the measurement approaches are potentially separable and therefore, while intangible benefits are readily accepted when they support existing intuition, they remain sufficiently subjective to limit their conclusiveness in decision making. Additionally, the ROI-centric measurement of tangible benefits has seemingly resulted in limiting the operational perception of M&S 'value' to the acquisition and procurement domains [4]. Therefore, given that the lens through which 'value' is perceived, defines how 'value' will be measured, and that measurement drives the very way in which a problem is shaped and subsequently understood, the lack of a broadly applicable measurement framework that embeds operational 'needs' as fundamental, limits the overall integration of M&S within the defence environment.

"You get what you can measure…and sometimes not even that much"

The Future Force Synthetic Environment (FFSE) Section of Defence Research and Development Canada, Ottawa (DRDC-O) has been established to provide an R&D centre of excellence in the area of Synthetic Environments (SE) and Capability Engineering (CE). In their fullest application, these fields are broad, far reaching, and interact with a significant number of activities conducted by many different R&D groups within DRDC, and many different capability and project planning, management, engineering, and support groups across the Department of National Defence and Other Government Departments (OGD). In advancing the integration of M&S/SE tools and processes, FFSE works very closely with M&S practitioners within defence, industry and academia and, in particular, with the Canadian Forces Experimentation Centre (CFEC) which has a mandate to lead the exploration and evaluation of emerging concepts to determine the capabilities required by DND/CF in the future and as such employs M&S tools and processes extensively [5]. Capability Engineering, in its broadest sense, supports defence Capability Based Planning (CBP) by providing 'system-of-systems' engineering rigour to the identification, definition and development of military capabilities facilitating the migration away from a platform-centric acquisition paradigm towards a holistic capability-based program inclusive of the people, process and materiel that constitute operationally effective forces. The

[1] SEBA is frequently employed within the Canadian defence context, paralleling SBA and other similar constructs.

unique coupling of FFSE's dual foci, CE and M&S/SE, has facilitated a convergence in measurement that shows promise to provide a broadly applicable and unifying structure. Capability Metrics have been developed to provide both strategic and diagnostic measurement on the attainment of operationally relevant military Capability within an "effects-based" construct. Extending the concept of desired "effects" for M&S itself, suggests additionally suitability to measure M&S 'value' to the operational community.

The paper provides background on the motivation and development of a Live-SE Utility Metric which sought to differentiate M&S 'value' to operational end-users in terms of Concept Development and Experimentation (CD&E) trials. This work evolved a renewed view of M&S 'value" and precipitated the subsequent development of an "effects-based" metric for M&S 'value'. A series of M&S-based exercises have begun to explore this "effects-based" M&S 'value' measurement framework and preliminary results are described in this paper. The paper concludes by describing an upcoming M&S-based trial which will continue to advance this work while beginning extend the measurement structure to more abstract applications as a means to explore its broadest utility.

2.0 AN OPERATIONAL PERSPECTIVE ON THE 'VALUE' OF M&S

In June 2004, FFSE developed and executed an SE-based trial that was designed to mirror the planned CFEC-lead August 2004 Atlantic Littoral ISR (Intelligence Surveillance & Reconnaissance) Experiment (ALIX). The ALIX Trial itself represented a live experiment within an experimental campaign plan developing and exploring Integrated ISR concepts for future CF operational employment [6]. The SE-based "ALIX" trial was shaped to offer mission rehearsal as a risk reduction exercise by familiarizing trial personnel with the terrain and scenarios involved in the experiment. The use of integrated live and SE-based trials to improve overall experimentation robustness is well recognized [7] and was further supported by this initiative. It is noteworthy that although the time period between the SE-based trial and the live experiment was quite short (approximately 60 days) and consequently some 'lessons learned ' in the SE-based trial were not readily transferable, many issues identified in the synthetic rehearsal were incorporated into the live experiment planning [5].

In November 2004, a separate workshop compared the live and SE-based trials as a means of advancing an understanding of both the structure and utility of SE-based support to CD&E activities [8]. The workshop included Defence Scientists, M&S practitioners and members of the military operational community. The workshop focused on the development of a common measurement approach in order to differentiate live and SE-based trials in terms of preferred suitability for various elements of the experimentation process. Additionally it was hoped that this measurement structure would further extend to evaluating how well both live and SE-based trials supported military operational capability assessments within a Concept Development construct employing a ***Capability Metric*** developed to support "effects-based" operational outcomes. In this development a military capability was defined in the broadest abstraction and paralleled existing Canadian Forces Capability Based Planning constructs (e.g., Command and Control (C2) or ISR represent Capabilities)[9].

The workshop developed a "Utility Metric" that differentiated specific strengths offered by an SE-based approach when compared to the live trial. Thirty-four specific features were described and contrasted between the two trial approaches seeking to identify which approach provided the most suitable environment, this included features such as: cost, credibility, safety, operational acceptance of results, environmental impact, controllability, and synchronization flexibility, as examples [5]. Figure 1 depicts the conceptual framework for the analysis. If each approach had equal suitability then one would expect complete overlap

between live and SE-based trials. Dominance by one approach would then imply greater overall suitability. The additional objective, to evaluate how well each approach supported measurement of the overall military capability offered by the experimentally tested concept (bottom area in Figure 1) employing the strategic (or end-state Capability Metric) was unable to be fully developed as insufficient analysis of the live trial data had been completed prior to the workshop. However, this remains an area of follow-on interest for the FFSE Section of DRDC-O as it could offer guidance to future planners as to how best to employ M&S in evaluating military concepts.

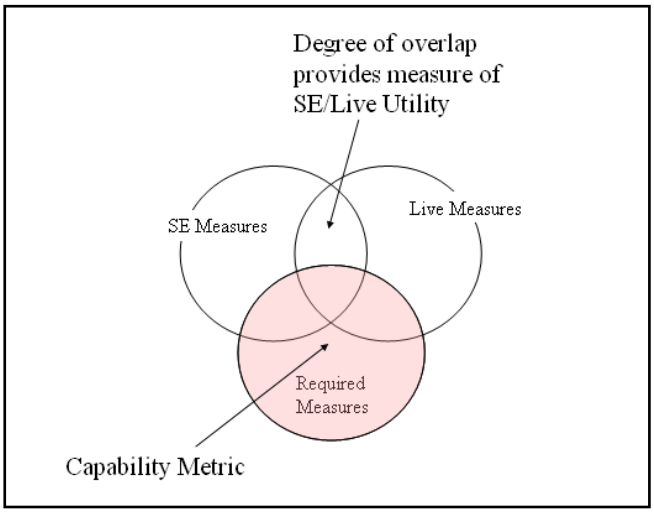

Figure 1: SE-Live Utility Metric developed in Atlantic Littoral ISR Experiment (ALIX) Workshop

While it is not the intent of this paper to present results of the analysis of the SE/Live Utility Metric developed during the workshop, analysis demonstrated that both "acceptability of results" and "perceived credibility" were rated by the operational community as heavily favoured within the live trial; whereas "predictive power", "controllability", "observability", and "data collection", although rated more suitable in the SE-based approach, were identified by operational end-users as not possessing sufficient 'reality'. Figure 2 illustrates the distribution and although there appears to be a slight suitability advantage offered by the SE-based approach when all 34 items are considered[2], this is very much offset by the operational end-user perception that live trials offer credibility [5].

[2] The workshop was dominated by M&S practitioners in terms of overall numbers and no weighting of importance was assigned to any characteristic [8].

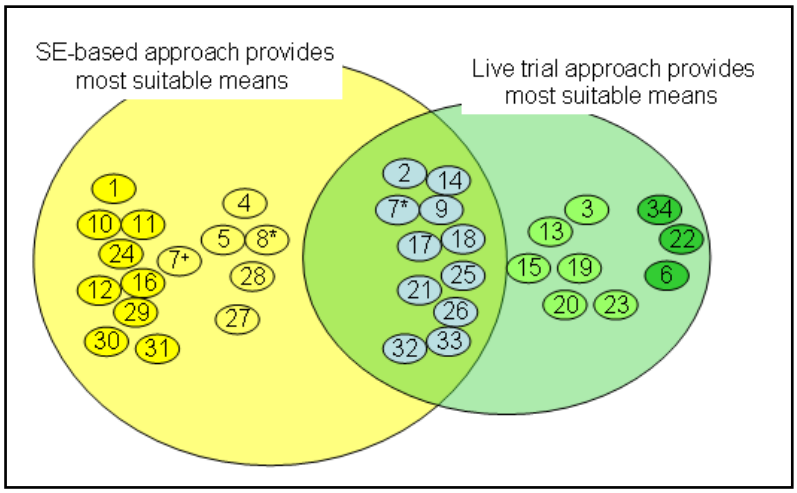

Figure 2: Utility Metric illustrating analysed features[3] and dominant domain (i.e., Live or SE-Based Trial). Complete data available in [5]. The data point distribution reveals that items within the overlap (e.g., 9=usability) were considered equally suited to either trial approach; whereas, items within the extremes (e.g., 1=Iteration ease (number of trial runs), 22=validity of results) were deemed more suitable to SE or Live trials, respectively. It is noteworthy that SE-based trials were generally seen as more suitable to the majority of measures; however, no specific weighting was employed.

Although there is an expectation that additional exploration of the SE-Live Utility Metric is warranted and therefore the results are not exhaustive nor considered conclusive, they further support a perceived limitation[4] associated with M&S from the operational military community. Interestingly, "cost" was identified as an advantage of the SE-based approach but only when multiple, repeated instantiations of a given configuration were assumed or in the event that substantial M&S re-use can be exercised [5]. Surprisingly, albeit limited to CD&E activities, "cost" was not distinctly seen as an advantage for SE-based trials. Additionally, any "cost" advantages that would form M&S 'value' were constrained by an operational end-user demand that the SE-based approach provide a 'faithful representation'[5] of the real world as credibility of results was firmly attributed to live trails. The fact that a live trial represents but a single data point, at a given instant in time, seemingly escapes consideration.

Activities associated with the development of the Utility Metric have drawn attention to the conventional view of M&S 'value', particularly when viewed through the lens of the operational community. In essence, it is arguable that M&S (as executed within the SE-based trial but potentially extensible to M&S applications addressing operational concept development in general) is not viewed as providing ROI as its primary 'value' and secondly, credibility of outcomes is questioned and seemingly centred on 'faithfulness' to perceived ground truth. Therefore, while both form intuitive conclusions, what is perhaps more relevant is that the outcome of the Utility Metric analysis prompted a renewed focus on the paradigm within which the M&S community has sought to position 'value'.

[3] The numbering system depicted here relates to the Table of Selected Features developed and analyzed within the workshop and additional detail can be found in the workshop reports [5].

[4] The 'limitation' recognized in this work is specifically associated with the use of M&S to support CD&E and therefore while a limited case it is not unreasonable to extend the limitation to M&S applications in general.

[5] This necessity seems to drive on-going Verification, Validation and Accreditation (VV&A) activities.

The framework under which M&S 'value' is measured exists within a dominant paradigm which provides the focal point from which exploration and analysis evolves. The dominant paradigm is consistent with accepted conventional understanding and becomes ingrained, influencing the choice of questions posed, the methods used to study them, and potentially the interpretation of any results [10]. M&S 'value' centred on ROI and intuitively accepted intangible benefits seemingly forms today's dominant paradigm; it is arguable that a new paradigm may be required when viewed from a military operational perspective and that this new paradigm could form a singular focus from which to evaluate M&S perceived 'value'.

3.0 AN EVOLVING 'PARADIGM' TO VIEW M&S 'VALUE' IN TERMS OF EFFECTS-BASED OUTCOMES

Figure 1 depicts a proposed conceptual overlap between Live and SE-based trials in terms of their respective suitability to address a ***Capability Metric*** which was directly related to a desired end-state military operational capability. This work leveraged on-going developments within FFSE that are being advanced to support the Collaborative Capability Definition, Engineering and Management (CapDEM) Technology Demonstration Project (TDP, i.e., ACTD-like) which has a mandate to define and validate a capability engineering process, and develop conceptual requirements for both integrated engineering and analysis tools and interdisciplinary collaborative engineering teams to support executing a Capability-based Planning (CBP) structure for future defence 'system-of-systems' configurations [11],[12]**.** Within a CBP structure, Capability Metrics define the desired strategic end-state for any military capability (e.g., Command and Control (C2) or ISR) and potentially serve as diagnostic measurements for progress toward closure of identified Capability 'gaps'.

To date, the Capability Metrics developed within CapDEM to support CBP have centred on the concept of "effects-based" Operations, employing a measurement structure developed for C4ISR[6] system analysis [13]. Five metrics terms – Range, Reach, Information, Agility and Persistence represent the broad "effects-based" outcome categorization (e.g., it would be potentially desirable to assess any approach to achieving an 'effect' in terms of its overall 'persistence', etc., when compared against desired end-state capability levels). Therefore, various 'systems' will provide Measures of Performance (MOPs) which will be aggregated into 'system-of-systems' configurations and assessed within the context of specific mission scenarios, providing Measures of Effectiveness (MOEs). MOEs are then traced to desired operational "effects" in terms of the Capability Metric [14]. Therefore, the **means** in which a desired military "effect" is delivered as the **ends** (e.g., detection of targets of interest) can be evaluated in terms of 'persistence', 'reach', 'agility' and 'information' requirements, and can be delivered across a 'range' of configurations as depicted in Figure 3.

In pursuing the broadest applicability, the Capability Metrics framework has embedded the concepts of Value-focused Thinking (VFT) in its structure [15]. Value-focused thinking (VFT) supports measurement of both objective and subjective criteria to evaluate options against organizational values rather than against each other. End-users define a value-hierarchy to which subsequent measurement is traceable, establishing a defendable decision environment. It provides an additional advantage by connecting the measurement of the various **means,** to the end-user who will employ those **means** to achieve the desired **ends** (i.e., "effects").

[6] Command, Control, Communication, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) – which represents elements of CBP areas such as C2 and ISR.

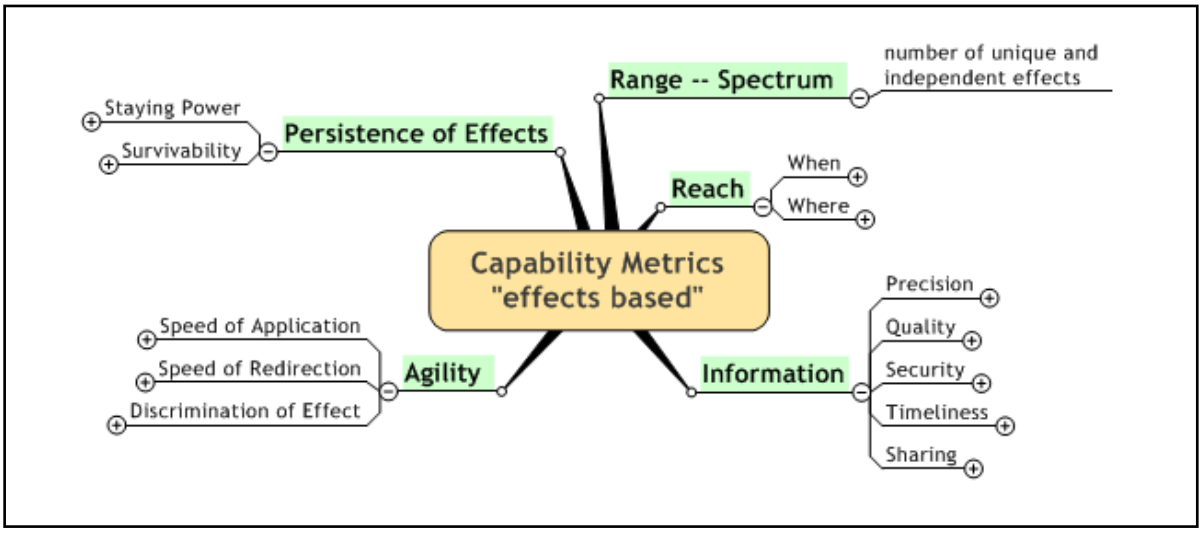

Figure 3: Capability Metrics Terminology based on US DoD National C4ISR Imperatives [13]. Although developed to support C4ISR-related decisions, the inclusion of Value-focused Thinking (VFT) as a decision context seemingly extends the framework's suitability to any "effects-based" measurement.

The "effects-based" Capability Metrics framework has shown significant suitability in supporting Capability assessments by providing a strategic measurement structure. For example, the present defence focus on Net Enabled Operations (NEOps) is similarly decomposed into a number of desired "effects" which can be measured by the five attributes depicted in Figure 3. In this instantiation, the desired military "effects" under an Effects-based Operations (EBO) concept become the '***ends***' whereas NEOps provides a '***means***'. In execution, Key Performance Parameters (KPPs) for operational effectiveness define the required levels of 'persistence', 'reach', 'agility', 'information', and 'range', typically developed through military operational scenarios, and the 'effects-based' outcomes are evaluated as to attainment of KPPs. This approach is consistent whether it be a singular system, within an isolated scenario (e.g., the addition of a UAV as an ISR asset for target detection in an urban environment) or a 'system-of-systems' configuration[7] across a breadth of anticipated missions (e.g., multiple, integrated sensor systems within an integrated ISR capability for both domestic and deployed operations). It is additionally suitable to evaluate the integration of new systems within legacy structures and has applicability to support CD&E activities as well, particularly in terms of defining 'target' future Capability states, and showed promise as a means to evaluate live and SE-based analysis by providing a consistent measurement structure.

However, given that "effects-based" outcomes are not exclusively limited to military applications and end-users could equally craft desired "effects" across a broad spectrum of application domains, the Capability Metrics framework has potential to be adapted and abstractly applied to provide consistent diagnostic and strategic measurement, regardless of domain. For example, through the development of a number of desired "effects" for CBP within the Defence Planning and Management (DP&M) system[8], and their subsequent

[7] In this context 'system-of-systems' is viewed through Maier's [12] five characteristics: Managerial and Operational Independence, Evolutionary Development, Geographical Distribution and Emergent Behaviour.

[8] This example is specific to the Canadian Department of National Defence and existing Canadian Forces strategic planning and program development processes; however, it should be equally applicable to any existing process in which a desired "effect" can be articulated.

decomposition into elements of 'persistence', 'reach', 'agility', 'information', and 'range', one could establish a measurement of 'value' for any program or process. In the specific case of CapDEM this has been pursued and a conceptual measurement structure developed to assess the 'value'[9] of a Capability Engineering approach toward improved execution of Capability-based plans [14]. Fundamentally, by designing the Capability Metric as a measurement approach for an "effect", the construct is rooted in the operational end-user's development of a desired "effects" statement and so firmly links 'value' to the ability to achieve desired "effects".

Therefore, given the apparent extensibility of the Capability Metrics framework, it can seemingly provide a structure to evaluate attainment of desired military capabilities within an Effects-based Operations construct through both strategic and diagnostic consistency while providing adaptability centred on "effects" (or outcomes). This additional adaptability implies a common approach to measure both the outcome, and the method by which the outcome was achieved; both product and process at varying levels of abstraction – centred on defined end-user 'values'. Could this approach shape a new paradigm for M&S 'value'?

4.0 APPLYING CAPABILITY METRICS WITHIN AN M&S BASED EXERCISE

The Joint Simulation and Modelling for Acquisition, Requirements, Training and Support (JSMARTS) Initiative [15] is a Canadian Department of National Defence, Assistant Deputy Minister Materiel (ADM(Mat)) lead activity to define a vision for the systematic application of modelling and simulation in the business of DND and across all phases of the life cycle of defence capabilities, identifying that M&S and SE technology will be developed and employed as a ***key enabling technology*** necessary to meet the objectives of Strategy 2020[10], the overarching guidance document for the Canadian Forces [17]. The JSMARTS vision argues for the "complete integration of modelling and simulation into the Joint defence community" [15] and while providing a conceptual roadmap is absent of any well defined measurement approach within which to assess incremental attainment of that vision. This is not meant as a criticism of the vision as it very much situates M&S in an important role for the CF and identifies the impact of M&S across the breadth of the defence community. Figure 4 depicts the JSMARTS defined breadth of application for M&S. What is perhaps most compelling is its architect is the defence acquisition community and so conceptually places the M&S vision within the acquisition and procurement domain. Therefore, it is reasonable that whatever measurement structure will evolve to evaluate the execution of the roadmap it will be centred on 'procurement-related' measures (e.g., ROI and associated tangible related benefits such as risk reduction) and so remain within existing M&S 'value' paradigms.

[9] For example, the introduction of Capability Engineering should provide increased 'agility' over existing planning and program development processes and therefore, if the desired "effect" was shorter planning cycles, closure on this identified 'gap' in performance could be assessed through changes in 'agility' providing a measurement structure to evaluate the 'value' of a Capability Engineering approach when applied to the 'status quo'.

[10] Although Strategy 2020 is identified in the ADM (Mat) JSMARTS Initiative vision document it is expected that CF strategic guidance will evolve and therefore, so too, the JSMARTS Vision.

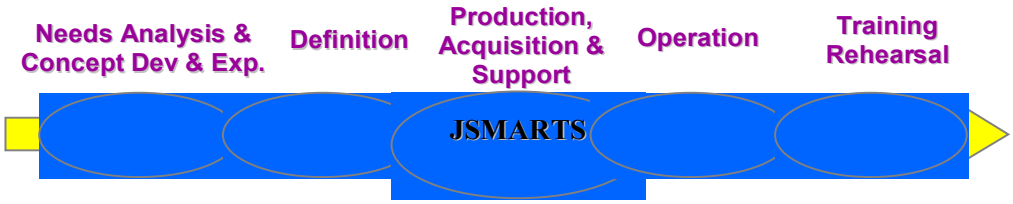

Figure 4: Conceptual domain of M&S highlighting the 'range' of applications beyond Acquisition and procurement [16]. The FFSE-lead *JSMARTS* Exercise concept aims to explore this application domain via a measurement focus centred on M&S 'agility'.

A similarly named yet conceptual separate initiative exists within the FFSE Section (see Figure 4 caption). The FFSE '***JSMARTS***', exercise series leverages the ADM (Mat)-lead, enterprise-level M&S vision as an overarching objective yet seeks to demonstrate, through a series of simulation events, how modelling and simulation technologies can be used at a national level[11], to demonstrate the value of this technology to a vast host of military and civilian applications, and to develop and improve Canadian forces systems and capabilities [18],[19]. Additionally, ***JSMARTS*** has established itself as an emerging way of conceptualizing the development of distributed simulation events by markedly moving away from large-scale, monolithic simulation-based exercises in favour of rapidly constructed, minimally developed simulation environments – characterized as a simulation-based 'pick up game'.[12] Guided by this conceptual goal, ***JSMARTS*** seeks M&S 'agility' coupled with exposure to and integration with operational end-users. By advancing the capability to provide rapidly developed and reconfigured M&S-based exercises, the operational community is able to quickly consider existing systems, evolving tactics, techniques and procedures, and the potential capability of new or as yet nonexistent systems all while generating unrealized transformational concepts through exposure to the simulation environment. What the exercise may lack in structure, fidelity or 'faithful' representations of perceived operational reality, is offset by speed and the ability to consider the as yet unconsidered. As the ***JSMARTS*** series advances, many of the traditional challenges M&S faces (see M&S Utility Metric earlier in this paper and "Lessons Learned" in [19]) will be overcome as the demand for M&S capability will be born of the operational community's needs, as a direct result of their exposure. In essence, the ***JSMARTS*** approach has the potential to invert the M&S 'supply-demand' curve and markedly increase transaction rates that will exceed the M&S resource base – a harbinger of change [20].

A key strategic objective of the FFSE Section is to 'push' M&S capability that covers the full spectrum[13] of its potential 'value' to the operator, in the field. In essence, to move M&S out of the lab and into the hands of the operator providing the capability to explore new concepts in the only environment ideally suited to understanding those 'things' that as yet do not exist. ***JSMARTS*** supports this objective.

[11] To date, JSMARTS has focused on national-level distributed simulation; in fact, ***JSMARTS 2***, is beginning to extend to municipal level participants and there is an expectation that the initiative could broaden to include international participants, albeit the additional levels of administration might negatively affect the ***JSMARTS*** objective of 'rapidly configured simulation'.

[12] The 'pick-up game' concept implies using already developed simulation-based resources in innovative configurations to evaluate concepts and federation development constructs. Essentially, participants offer what they have at present to achieve 'ends' rather than designing a bottom-up, requirements based simulation based exercise. A key aspect is to assess and develop M&S 'agility'.

[13] In this regard – spectrum implies M&S for CD&E, options analysis, design, etc., rather than its more familiar training support applications as seen from an operator's perspective.

4.1 Developing Capability Metrics for M&S "effects"

Presently, FFSE is executing ***JSMARTS 2***, the second collaborative Government-Industry-Academia rapidly configured M&S-based exercise. In this instantiation, a public safety scenario has been developed that includes an inter-agency response and associated C2 requirements to a radiological hazard deployed in a populated area of a Metropolitan Canadian city. Although C2 issues will undoubtedly evolve throughout the scenario's execution, the primary objective is to assess various 'system-of-systems' configurations supporting hazard detection, localization and containment.

JSMARTS 2 will employ the Capability Metrics depicted in Figure 1 to evaluate the 'system-of-systems' configurations in terms of achieving desired operational "effects".[14] An "as is" detection capability will be developed based on existing assets and processes defined in select guidance documents (e.g., city emergency response plan, etc.) and where possible these are modelled within the scenario. Additional sensor systems have been added (e.g., UAV equipped with radiological detector) and the new capability state assessed in terms of the Capability Metrics (the various terms, i.e., 'reach', 'range', etc., will be decomposed into a number of sub-elements that provide suitable measurements, both objective and subjective). Greater detail on the approach is available in [14].

However, by viewing the Capability Metric at an ***additional*** level of abstraction it provides a framework in which to evaluate M&S 'value' itself in terms of its contribution to achieving a desired "effect" for the operational end-user. By viewing the 'value' of M&S, specifically through the paradigm of "effects", one can conceivably re-align to address M&S-centric 'persistence', 'reach', 'agility', 'information', and 'range'. For example, operational end-users may demand a resultant effect consistent with 'persistent' (e.g., 24/7) training environments in which traditional M&S-based training would demonstrate 'value' exceeding live training exercises. Moreover, the 'reach' (or depth of application) and 'range' (or breadth of application) of M&S-based analysis could demonstrate considerable 'value' in the realm of CD&E, a domain in which future 'systems' may be solely conceptual and the desired "effect" to have an ability to assess and evaluate their potential. Additionally, 'information' characteristics of M&S-based analysis would clearly demonstrate 'value' in terms of data capture, flexibility, and synchronization; whereas in recognizing the inherent demand for a 'faithful' representation of reality, aspects of 'information quality' and 'precision' could be applied.[15] Finally, and perhaps most importantly, 'agility' seemingly shows the greatest promise in establishing a new paradigm within which to frame M&S 'value'. Figure 5 provides a notional recasting of the Capability Metrics framework centred on M&S "effects" in a purely descriptive fashion. Ultimately, end-user desired "effects" (or outcomes) from M&S will serve to define the Capability Metrics decomposition in this application.

It is somewhat noteworthy to further highlight M&S 'agility'. This is not to propose that 'agility' in isolation of the of the other "effects-based" Capability Metrics should be pursued but rather to suggest that the greatest potential 'value' to the operational community lies in the speed with which M&S can support decision cycles. In fact, it can be argued that in today's dynamic global security environment, when coupled with the increasing pace of technological advance, future military decision makers will 'value' speed in decision making above all else – including precision, which will simply form an element of the overall risk assessment associated with the decision. In fact, it has been proposed that one of greatest barriers facing the use of M&S to support the short planning cycles of today's operations is the time required to generate scenarios [21]. This

[14] While it was anticipated that ***JSMARTS 2*** would be performed in Sept 2005, unavoidable delays have been imposed and as such a report on the ***JSMARTS 2*** use of Capability Metrics is not yet available for summarization here.

[15] In some regards, 'information quality' is akin to M&S Verification whereas 'information precision' conceptually parallels Validation.

suggests that the present focus on ROI and other procurement-centric measures of 'value' may be disingenuous to advancing M&S into the next realm of application – rapid decision support. Perhaps M&S offers the only obvious domain from which the required 'agility' will emerge.

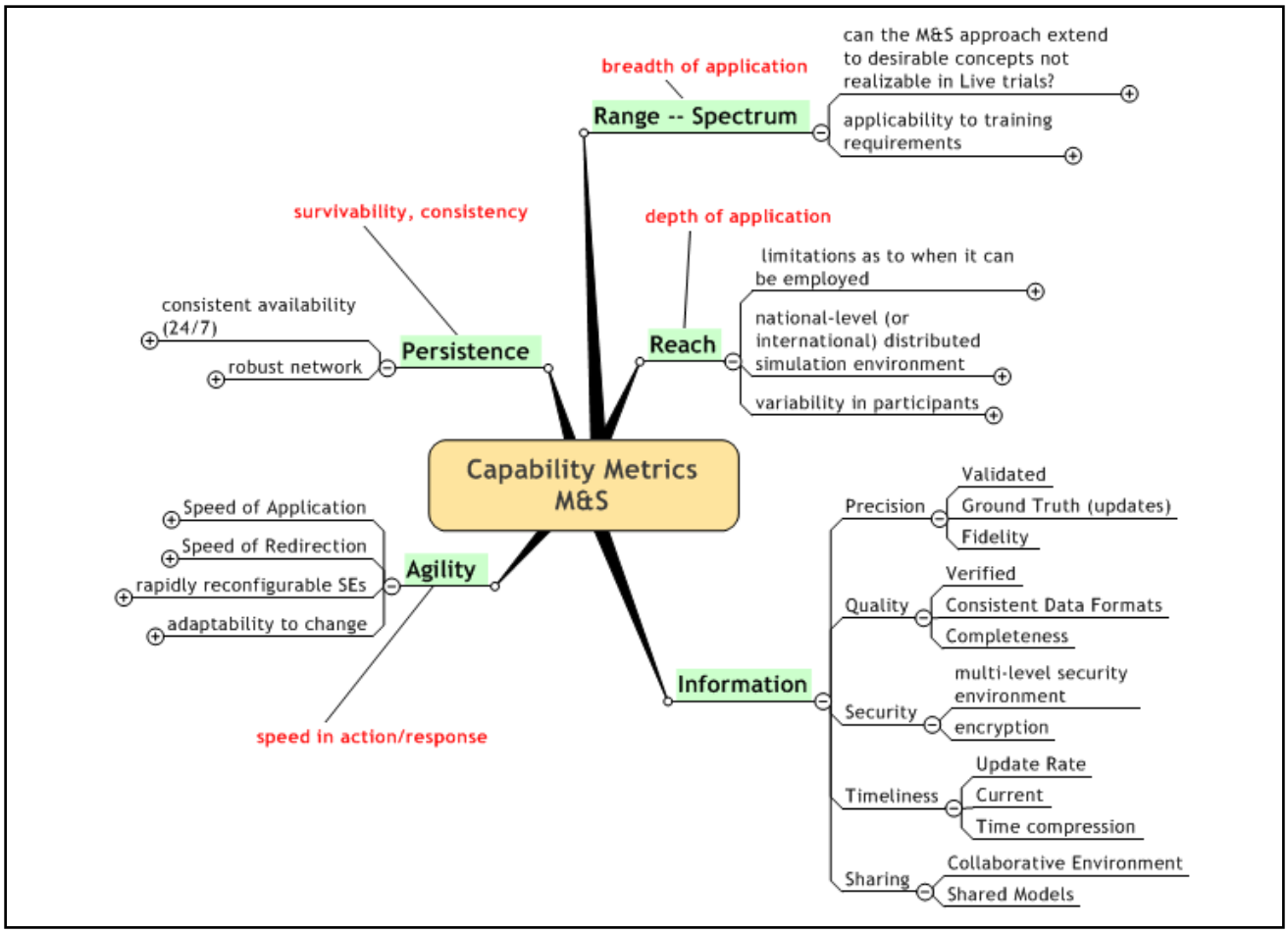

Figure 5: Notional example of the Capability Metric applied to M&S 'value'.

5.0 SUMMARY -- PARADIGM SHIFT IN THE 'VALUE' FOCUS OF M&S: FROM COST EFFECTIVENESS TO DECISION SUPPORT EFFECTIVENESS

Given the premise that any action demands measurement in order to understand where additional action is necessary and to appreciate how well any action is incrementally achieving a desired outcome, a measurement structure must provide strategic information to define the goal, and diagnostic information on its incremental attainment. A single, consistently defined and developed framework has appeal. Additionally, if this same structure is rooted in the most fundamental organizational objectives it has increased potential to remain connected to those who must execute the actions. Given that what we define to measure, and how we plan to measure, defines the paradigm and shapes the very thinking about the problem, an "effects-based" metric shifts both the measurement approach and the lens through which it is viewed. In the specific case of M&S

'value', the application evolution toward acquisition and procurement seemingly positions financial-centric measurement, typically in the form of Return on Investment (ROI). It is arguable whether the ROI lens has limited the further exploration on the 'value' of M&S to a narrow focus. The re-alignment to an "effects-based" measurement structure enables a consistent approach with broad applicability in which ROI can readily exist if so 'valued' as a desired "effect".

A series of inter-related studies underway within the Future Force Synthetic Environment (FFSE) Section at Defence Research and Development Canada (DRDC), Ottawa, have begun to explore the breadth and depth of applicability of an "effects-based" Capability Metric, which while originally focused on supporting Capability Based Planning has proven suitable as a means by which both M&S-based outcomes and methods can be evaluated. The development of a Utility Metric, which compared Live and SE-based trials as to their respective suitability for Concept Development and Experimentation activities, while generally supporting existing, intuitive expectations, revealed some unexpected results which precipitated our focus on M&S "effects". The subsequent convergence of the FFSE ***JSMARTS*** initiative, which seeks to advance M&S 'agility' in supporting effective decision making with a 'push' to put M&S tools, techniques and processes into the hands of the operational community, has additionally highlighted the suitability of the Capability Metric.

The operational community seeks 'agility' in decision making within a military Capability Based framework in which desired "effects", or mission outcomes, serve as the focus. By providing a consistent strategic and diagnostic measurement approach, based on "effects", both end-state and incremental attainment can be evaluated. The fact that future military capabilities may be wholly conceptual, positions M&S has having particular 'value' in supporting those decisions. By measuring M&S 'value' within an "effects-based" metric both the ***ends*** and ***means*** can be evaluated within a single structure. The structure has potential to shift M&S 'value' into a new paradigm in which decision effectiveness, driven by 'agility', becomes the yardstick.

References

[1] Brown, C. David, PhD, Col Gordon Grant (CF), LTC Donald Kotchman (USA), Col Robert Reyenga (USA) and Lt Col Terrence Szanto (USAF), Building a Business Case for Modeling and Simulation, Acquisition Review Quarterly (Fall 2000), Defence Acquisition University (DAU), http://www.dau.mil/pubs/arq/2000arq/brown_fall00.pdf

[2] Gordon, Steven, C., PhD, Economics of Simulation Task Force, SISO Economic Study Group Spring 2002, http://www.msiac.dmso.mil/ia_documents/SPIE_Economics_task_force.doc

[3] McMahon, R., Modeling and Simulation Return on Investment (ROI) "Real Savings" Vs. Indirect Savings and Cost Avoidance, US Army Research Laboratory, Human Research and Engineering Directorate.

[4] Feasibility Study on Modelling & Simulation Technology in Support of Simulation Based Acquisition (SBA), RTO-TR-064 (AC/323(NMSG-003)TP/06, Feb 2003.

[5] Canadian Forces Experimentation Centre (CFEC) Introductory Briefing, February 2002, http://72.14.207.104/search?q=cache:EwNbMi29rt4J:www.afceaottawa.ca/presentations/AFCEAbrief5Feb02.ppt+CFEC&hl=en

[6] Atlantic Littoral ISR Experiment website, http://alix.canmarnet.gc.ca, July 2004.

[7] United States Joint Forces Command, Understanding Joint Warfighting Experiments, October 2004.

[8] Developing Common Metrics across Synthetic Environment and Live Experiments, DRDC Ottawa Workshop on Capability Metrics for CapDEM TDP, 22 - 23 November 2004, Defence Research and Development Canada (DRDC) Ottawa.

[9] Strategic Capability Based Planning for the Canadian Forces, http://www.vcds.forces.gc.ca/dgsp/pubs/dp_m/cbp_e.asp

[10] Kuhn, Thomas, The Structure of Scientific Revolutions, University of Chicago Press, 1962.

[11] J. Pagotto and R.S. Walker, DRDC Ottawa; *"Capability Engineering – Transforming Defence Acquisition in Canada";* presented at SPIE Conference, Orlando, FL, April 2004

[12] Maier M W, "*Architecting Principles for Systems-of-Systems",* Nov 1998, http://www.infoed.com/Open/PAPERS/systems.htm

[13] Program Synchronization Initiative (U), Joint C4ISR Decision Support Center, Kelly, D., and Staats, R., Study Leaders, Oct 2003

[14] Pogue, C., CapDEM Metrics Framework – Applying Evolving Capability Metrics to CapDEM – 'Walking the Talk', January 2005.

[15] Keeney, Ralph, L., Value-Focused Thinking, a Path to Creative Decision-making, Harvard University Press, Cambridge, MA, 1992.

[16] The Joint Simulation and Modelling for Acquisition, Requirements, Training and Support (SMARTS) Initiative: A Vision for enabling Strategy 2020 through the application of Modelling and Simulation in DND, March 2004, http://admmatapp.dnd.ca/cosmat/dmasp/downloads/ModellingSimulation/vision.doc

[17] Shaping the Future of the Canadian Forces: A Strategy for 2020, Vice Chief of Defence Staff, 1999, http://www.cds.forces.gc.ca/pubs/strategy2k/intro_e.asp

[18] JSMARTS M&S/SE-based Exercises – "the pick up game", Future Forces Synthetic Environment Section, Defence Research and Development Canada, Ottawa, http://www.ottawa.drdc-rddc.gc.ca/html/script_jsmarts_e.html

[19] A.L. Vallerand, B. Kim, R. Youssef, P. Hubbard, D. Skinner, B. Johnson, B. Murray, S. Poursina , C.M. Herdman, M. Gamble, L. Hagen, D. Bleichman , and K. Gladstone, R. Kruk, R. Lavoie, D. Kurts, SYNTHETIC ENVIRONMENTS AT THE ENTREPRISE LEVEL: OVERVIEW OF A GOVERNMENT OF CANADA (GOC), ACADEMIA and INDUSTRY DISTRIBUTED SYNTHETIC ENVIRONMENT INITIATIVE, Technical Memorandum, DRDC Ottawa TM 2005-130, Canada, April 2005.

[20] Cebrowski, Arthur, K., Adm, Inevitable Surprises: Seizing the Opportunities, http://www.defenselink.mil/transformation/cebrowski_paper_20041216.html

[21] Blais, C., Semantic Web Technologies for Military Modeling and Simulation, cited to CAPT Jeff Kline, (USN) NPS Systems Engineering (August 2004), http://www.movesinstitute.org/Openhouse2004slides/blaisSemanticWeb.ppt