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Abstract

As military command and control (C2) applications evolve and become immersed within a growing net-centric operational environment, the complexity of interactions among component C2 enterprise capabilities will rapidly increase. The adoption of a Service Oriented Architecture (SOA) approach to C2 development, coupled with the incremental fielding of Internet Protocol (IP) based Global Information Grid (GIG) capabilities, will serve as the principal catalysts for this scenario. As a result of the sheer number of anticipated web service interdependencies, analysis and assessment of C2 behavior at the enterprise scale will be both necessary and challenging. This paper will provide an initial discussion of the emerging need for such analysis and will suggest some important implementation concepts to be considered, each of which could significantly impact future enterprise systems engineering (ESE) processes.

Preface

This report introduces and discusses new and emerging modes of thought that are increasingly being recognized as essential to successful systems engineering in enterprises. This new systems thinking is emerging at the intersection of seminal ideas from modern system thinkers, the broad discipline of information technology, and the theory of complex adaptive systems, particularly those from evolution biology and social systems. Part of this new systems thinking requires a replacement of the notion that specific engineering outcomes or goals can always be assured with one that seeks to shape, improve, or increase the value of engineering outcomes through thoughtful interventions in the ever-increasing numbers of circumstances in which we are not fully in control.

This report is one of a preliminary series of nine volumes that define and examine key building blocks of the evolving field of enterprise systems engineering:

Volume 1: Enterprise Characteristics and Challenges
Volume 2: Systems Thinking (New and Emerging Perspectives)
Volume 3: Enterprise Architecture (Application Across the ESE Spectrum)
Volume 4: Enterprise Management (Processes to Bridge Theory and Practice)
Volume 5: Enterprise Opportunity and Risk
Volume 6: Enterprise Activities (Evolving Toward an Enterprise)
Volume 7: Enterprise Analysis and Assessment
Volume 8: Capabilities-Based Planning Analysis
Volume 9: Enterprise Research and Development (Agile Functionality for Decision Superiority)

The volumes are intended as guidance for researchers and practitioners who are expanding their horizons from traditional to enterprise systems engineering. The volumes range from the complex characteristics and behaviors of enterprises to the challenges they pose for engineering and technology. They examine the impacts of enterprise processes and leading-edge technologies on the evolution of an enterprise. No attempt has been made to tightly integrate these documents - some material is repeated, some approaches may be slightly different. They were produced under a D400 effort to "Write the Book" on enterprise systems engineering, and at this juncture, they are being published as various works in progress - loosely coupled and evolving.

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1 Introduction

This is not a research paper. There are no long lists of programs that have performed analysis and assessment at the enterprise level for reasons related to the development or operational use of command and control (C2) systems or networks. There is no statistically based or anecdotally derived set of "tried and true" best practices from which to generate a few insightful recommendations. Enterprise analysis and assessment (EA&A), as it will be defined in this paper, is a new undertaking, but one that will be necessary in order to permit thoughtful, proactive, robust evolution of the C2 enterprise. For background, the concept of the C2 enterprise is discussed in (Rebovich 2005).

Why the assertion that there needs to be a new undertaking -- a new twist on the historical types of analyses performed in the past in support of various systems engineering goals? There are four main reasons behind this assertion. First, we are moving into an era in C2 where our infrastructure and operational paradigms are changing in fundamental ways. One can argue if (or how much of) the Global Information Grid (GIG) exists today, but it certainly doesn't exist in the deployed form that most envision it to be. As that happens incrementally, and we move from message-based information exchanges between known entities over dedicated communications links to more of an internet-like approach, we must be able to assess how well our emerging net-centric C2 applications will perform under a wide variety of new operating conditions that neither lend themselves well to current methods of analysis and assessment, nor to the capabilities of the tools that we routinely use today in support of these efforts.

Second, given an emerging GIG infrastructure relying on internet protocol (IP) standards, the introduction of highly interrelated C2 services distributed throughout the C2 architecture (vice traditional, more independent C2 applications) will have a major impact on mission performance considerations. This Service Oriented Architecture (SOA) approach to enterprise interoperability, leveraged heavily from the commercial information technology (IT) business sector, also doesn't exist today in any meaningfully deployed way within the Department of Defense (DoD). Individual programs are just beginning to develop and field initial offerings of web-enabled C2 applications representing small pieces of their overall capabilities. Therefore, there has not yet been a burning need to perform analysis and assessment of net-centric C2 enterprise issues. But this need will arise soon, and there must be some thought dedicated now to enabling the emergence of possible methods and techniques that will be required by C2 developers and operators in the near future. As an example, all programs will be required to show how they support the Net-Ready Key Performance Parameter (NR-KPP). The NR-KPP will be used to assess required net-ready attributes for the information exchange as well as the resulting end-to-end operational effectiveness.

Third, the fact that our threat environment morphs and becomes more complex over time will drive us to be more responsive to world events to the point of becoming proactive in examining potential operating conditions. In order to accomplish such a goal, we need a more flexible infrastructure that will enable users and developers to quickly assess the potential of emerging C2 capabilities to address new, potential and perceived threats.

Finally, our users expect increased functionality and better performance from C2 systems and capabilities over time. Simply maintaining the status quo with respect to capabilities and execution performance will mean that we have not exploited the benefits of net-centricity. Providing a wealth of new capability options to users is only acceptable with an accompanying improvement in execution performance, otherwise, the enhanced set of capabilities will utilize even more bandwidth and processing resources than they do today.

Therefore, we need a way to ensure the stability, scalability and robustness of C2 capabilities as we progress toward net-centric operations. However, if every next-generation system or capability will be dependent upon one or more other systems or capabilities in a net-centric, GIG/SOA C2 architecture, does this mean that one must model the whole world or tap into every program's assets in order to analyze any issue for a given program or mission? Using traditional systems engineering analysis methods, one could argue that this might be a logical consequence. Of course, this approach would be completely impractical. So, how can analytical needs be satisfied for enterprise scale C2 issues, and what are those issues?

EA&A will be defined not as the ability to analyze the complete inner workings of an entire C2 enterprise at once, rather, EA&A will be defined in terms of an ability to characterize the behavior of entities or capabilities that are immersed within an enterprise construct. EA&A will emphasize a robust "What if?" approach versus the traditional, highly scenario-dependent attempts at "prediction". There will be shown to be a critical need to leverage modeling and simulation (M&S) capabilities, with a key role for real-time operator-in-the-loop (OITL) and/or hardware-in-the-loop (HWIL) capabilities, though not necessarily the traditional systems engineering use of any of these. This paper will define EA&A for C2 as the ability to robustly analyze and assess potential outcomes derived within enterprise architecture constructs to permit an understanding of fundamental behaviors. EA&A will relate strongly to enterprise opportunity and risk assessment, aiding in the generation of risk management options for C2 capability developers and C2 operators.

The enterprise analysis techniques proposed in this paper are intended to permit proper analysis of operational situations and enable more informed subjective assessment of the mission execution from an operational perspective. The results derived from this approach to analysis and assessment will permit the insights produced to be applied across a wide range of specific architectural, technical and operational conditions for both

development/acquisition as well as operational purposes. Thus, this paper will identify the expected utility of the insights to be gained through adoption of EA&A principles.

2 The Need

C2 EA&A must ask and answer a different set of questions than traditional systems analysis. Emerging paradigms in the employment of C2 capabilities (e.g., net-centric operations), their associated information technology infrastructure (e.g., SOA) and the acquisition of those capabilities (spiral development) are significantly impacting traditional acquisition responsibilities such as risk management and test and evaluation (T&E). The diminishing utility of traditional T&E and certification processes and approaches when applied to quickly evolving net-centric applications motivates a need to steer programs toward supplementing these traditional approaches with more viable alternatives to ensure the achievement of desired behaviors at the C2 enterprise scale. The analytical components of T&E, risk management and other activities must be addressed within an increasingly complex operational environment.

At the enterprise scale, it will be shown to be much more important to characterize behavior across a set of operating conditions, rather than performance according to a specific scenario (or perhaps a few variants) with all the associated assumption and caveats. The idea is to characterize the performance of the overall capability to execute the required mission under a wide range of operating conditions, no matter how they might be envisioned to occur. The analytical challenge is to consider the full range of possible conditions, even remote possibilities, that might occur to ensure robustness. This includes dealing with adversaries that could be acting to defeat the C2 capabilities under assessment. In fact, an environment that not only permits simulated attacks to occur, but actually facilitates this behavior by certain participants will allow users to quickly and concretely understand vulnerabilities of current or proposed capabilities. This example points out the need to have early and continuous operator involvement in the C2 EA&A process. The challenge here is to provide an inexpensive and flexible infrastructure to enable this to occur on a regular basis.

While the need for C2 EA&A is not critical today, it is coming. The current state of GIG and SOA fielding is providing some time to permit EA&A to be developed and better understood. For example, there continues to be debate about the ultimate requirements for the GIG when it is fully implemented. Development issues within the Joint Tactical Radio System family of systems has also stretched out the fielding of net-centric capabilities. Also, the transition of SOA technology from the commercial workplace to the DoD has encountered some bumps in the road because of real world issues such as non-assured military communications. Non-assured communications was never a key commercial SOA technology consideration because of the massive telecommunications infrastructure available to financial institutions and other large corporations, who are the major clients driving commercial IT standards.

However, even with the large issues described above, key stakeholders are making progress toward IP-based network operations. Surrogate, near-term, scaled-down concepts and initial implementations of future wideband IP networks (e.g., Interim Capability for Airborne Networking, Tactical Targeting Network Technology, etc.) are blossoming in the interim while the major building blocks of the GIG are in development. C2 programs (e.g., Theater Battle Management Core Systems etc.) are incrementally web-enabling certain portions of their capabilities. Finally, industry is moving ahead with concepts such as Enterprise Service Bus prototypes. Within the next few years, there could be enough fielded SOA-based capability riding on a "GIG-lite" infrastructure that C2 EA&A issues could begin to be thrust to the forefront within both the operational and acquisition communities.

So what? What are the advantages of understanding how capabilities within a C2 enterprise behave under normal and unusual operating conditions? How will this knowledge help us? First, there are currently a plethora of strategy, policy and guidance documents that describe how to design and implement net-centric C2 capabilities. Many of these documents are quickly outdated, or written at a very high level, or even contradictory in places. The sheer volume of this guidance, while well intentioned, becomes difficult to comprehend, apply and arbitrate at the C2 enterprise level. We *do* need a way to evaluate compliance with key design principles, but we *don't* have our acquisition personnel sufficiently enabled to identify these "needle in the haystack" key implementation strategies. A process and accompanying analysis environment to allow the most successful strategies, policies and guidance to emerge and be identified will be critical to the evolution of net-centric C2. Those applications that can work effectively under a wide range of operational conditions will have embodied the key principles of net-centricity and probably avoided many of the unnecessary ones. It will be become increasingly important to down-select within our continually growing set of strategy, policy and guidance documents to convey to developers what is critical and what is not. It will then be possible to evaluate compliance with only the most fundamental principles.

Second, if operational personnel can begin to understand under which sets of conditions they will experience difficulties executing their missions, they can proactively develop temporary, emergency workarounds and explore other means of accomplishing critical tasks within an operationally safe environment. During subsequent deployments, not only will they be better prepared for the uncertainties of real world operations, but they might even be able to identify impending problem situations to become more proactive and less reactive.

Third, EA&A might ultimately enable the evolution of an entirely new business model for the acquisition of future DoD C2 capabilities. With the distinct (and perhaps likely) possibility of numerous web services being developed with overlapping functionalities, it will be almost impossible to continually dictate which are the "preferred" or "mandated"

services to be used. A set of services might perform the exact same function others (e.g., targeting, data fusion, resource tracking, etc.), but some might be extremely inefficient for a particular community to use. On the other hand, another set of services might appear to provide the "gold standard" of capabilities to a wide user base, but end up providing lots of extra complication and headaches for users. Stable, basic services built on trusted, legacy software architectures (e.g., wrapped legacy code) might win out over less stable, embryonic services build on a more robust and extensible software backbone in the short term. However, the balance might very well shift over time as the legacy-based applications run into increasing development problems (cost, schedule and performance) as they climb the tough hill to adapt to new operational paradigms as underlying technologies evolve. Eventually, an EA&A environment could lead to a competitive situation where services are posted in an operationally realistic evaluation arena and users migrate to those that work best to satisfy their needs. Those services that are widely used (or are needed by high-profile users) would thrive and receive additional resources for evolution, while those that are seldom used would be left to wither.

All engineering-based product development requires some form of analysis, often multiple forms, and often at multiple points during the lifecycle of individual systems. Systems engineering, risk assessment/management and T&E support are often the major drivers of systems analysis activities. There will always be a need for some amount of highly detailed systems analysis within individual programs.

Time and cost are critical considerations. M&S-based analyses can shorten analysis timelines because system model development can precede system development. In fact, many analyses performed in support of system level issues to date have already been M&S-based, to one extent or another. However, these efforts have not typically well coordinated from one phase of program acquisition to another, with an implication of little M&S reuse due to disparate development and domain advocacy for unique toolsets. There is typically even a greater disconnect between those M&S-based analysis activities performed in support of acquisition and those performed in support of operational activities (especially training).

DoD guidance is another important driver for systems analysis. There are a number of areas within the realm of systems analysis that are amenable to capabilities-based analysis and architecture-based analysis. These include basic interoperability assessments, information exchange requirements, function use/utility evaluations, etc.

However, there are significant inherent limitations within the most widely used commercial architecture tools. A number of system architecture tools have the ability to run "dynamic" executable versions of use cases typically employ static input data files or statistically generated message input data to drive information through the architecture to identify information bottlenecks, calculate throughput statistics, show high/low use areas,

etc. This flavor of analysis might be useful as a first cut at systems analysis, but it lacks the ability to take the analysis to the next level of sophistication, including real-time operational scenario execution with operator participation as well as the ability to efficiently inject realistic system functionality (e.g., processing logic for C2 systems) because of the lack of environmental considerations as well as non-trivial runtime implications.

Finally, systems analysis activities have usually been focused on addressing questions that are of critical importance to program milestone decisions. These scope of these activities has traditionally depended upon the analysis tools and capabilities resident within a given program, including the associated contractor (or contractor team). Limited analysis resources within a program can often restrict the application of analysis capabilities to only those topics that can be studied over a period of a few months. Normally, collaboration among program offices to address questions unique to only one program's acquisition milestone needs is rare. It is extremely difficult to match up milestone dates across program with sufficient lead time to coordinate the collaborative execution of major tests and demonstrations.

As a direct result of the realities of tightly focused analyses needs within C2 programs, for example, the following are common practices observed from the conduct of systems analysis efforts across a number of such programs, with benefits and drawbacks (the "Cons" associated with each class of systems analysis effort make them inappropriate for C2 EA&A because they impact the inherent flexibility necessary to accomplish the EA&A objectives discussed earlier) indicated for each:

- Emphasis on specific Use Cases and associated scenarios
  - Pro: they help flesh out particular Concept of Operations and Concept of Employment issues
  - Con: they are required to undergo a lengthy accreditation process and are difficult to change once approved
- Trust placed in only verified, validated, accredited and/or certified C2 software applications (including associated system models that are usually not shared outside of the program)
  - Pro: supports program configuration management objectives and T&E requirements/guidance
  - Con: trust mandated no matter how flawed the processes are known to be
- Mapping of numerous measures of performance (MOPs) to a smaller group of higher-level measures of effectiveness (MOEs)
  - Pro: identifies data collection requirements
  - Con: consensus process places little analytical rigor behind the choices of mappings

- Model-based system performance predictions to fill gaps in requirements definitions (i.e., eliminate "To Be Determined" system requirements)
    - Pro: provides concrete guidance to contractors and defines analysis tool development/integration needs
    - Con: produces highly-scenario dependent analysis results with numerous caveats, leading to the inability to extrapolate results or utilize them to gain an understanding of alternate employment concepts
- Large HWIL node integrations to support T&E needs in interoperability arena
    - Pro: establishes long-term working arrangements with key partners
    - Con: expensive to achieve, leading to ever increasing resistance to change for other uses (once integrated and working properly)
- Large-scale, infrequent Joint experiments/demonstrations to look at emerging capabilities
    - Pro: program office team learning associated with pre-event integrations
    - Con: demonstrations (and experiments structured like demonstrations) provide little "leave behind" to leverage and evolve once the event is completed
- Downstream insertion of third-party hardware and software instrumentation "probes" for measurement or diagnostic purposes
    - Pro: collects data for subsequent performance analysis
    - Con: normally causes perturbations when inserted within a system being monitored, affecting overall results
- Measuring whatever we can
    - Pro: provides clues to some categories of system performance issues
    - Con: difficult to relate lower level measurements/metrics to desired outcomes

3 Essential Characteristics of EA&A

In order to address questions related to the characterization of expected behaviors of C2 capabilities over a wide range of operational conditions, EA&A must de-emphasize the utility of comparing detailed metrics against specific individual requirement values, whether the metrics are derived from measurement, simulation or estimation. EA&A must instead look for break points where capabilities are either significantly enhanced or totally disabled.

Since EA&A must identify sets of simultaneous conditions responsible for noticeable changes at the mission effectiveness scale, it must emphasize real-time OITL assessment within an environment that is almost identical to an actual operational setting. Interestingly, EA&A must go as far as actually encouraging proactive, asymmetrical threat attacks to occur under non-destructive, non-life-threatening conditions. It must also foster a culture amenable to publishing and encouraging the external use of system/capability representations (e.g., models).

Key characteristics of EA&A to be discussed in this section are as follows:

- Multi-scale analysis
- Early and continuous warfighter operational assessments
- Lightweight, portable M&S-based C2 capability representations
- Developmental software versions available for assessment
- Minimal infrastructure
- Flexible M&S, OITL and HWIL capabilities
- In-line, continuous performance monitoring and selected forensics

3.1 Multi-Scale Analysis

In many instances, traditional standalone analysis approaches will be sufficient for systems analysis and below. However, these traditional systems analysis approaches are generally inadequate for considering multiple "agent" (user, system, sub-system, etc.) interactions and multiple scales of resolution within the enterprise. They often do not effectively consider the significant effects of human interaction with systems. We are increasingly observing that, as systems evolve over time, interact with other systems and generate streams of information for human decision-makers, phenomena emerge that could not be anticipated through the use of traditional systems analysis techniques. In fact, even the differences in scale/scope of enterprise level analyses will drive the need for multiple analytical approaches. Emergent phenomena will require a synergistic application of different approaches to address multi-scale analysis at the enterprise level.

What is the difference between multi-scale and multi-level with respect to a C2 enterprise, and why is the notion of multi-scale analysis most appropriate? The idea of multiple levels of analysis relates strongly to systems analysis, in particular, to analysis of non-complex (i.e., linear) systems. Very briefly, linear systems can be successfully analyzed through more traditional systems engineering techniques, such as functional decomposition. Analysis can be performed at the "piece part" level and integrated at higher levels to properly characterize overall system performance. A C2 enterprise does not behave according to the rules of linear systems theory. A C2 enterprise is an inherently complex system and, therefore, should be analyzed as such. A much more in-depth treatment of this subject can be found in (Kuras 2004).

The primary focus of EA&A is on the highest scale (i.e., level of resolution) applicable to C2, which is at the mission effectiveness scale. At this scale, the emphasis is on non-traditional analysis issues such as robustness, flexibility, fitness, etc. A critical objective is to identify operating ranges for systems and capabilities operating at lower scales that enable acceptable mission execution. In other words, there are normally wide ranges of system/capability performance at lower scales within which no discernable effects can be observed at the highest scale or resolution (mission effectiveness scale). Even significant deviations in communications throughput, sub-system reliability, platform processing speed, node architecture make-up, choice of web service provider, etc., will often not noticeably affect a user's ability to execute a particular mission. Key questions to ask at the mission effectiveness scale are, for example:

- What behaviors emerge under stressing conditions?
- What are the minimum system and operational architectures required?
- How can errors can be overcome?
- Etc.

It has not yet been established how many distinct scales exist within a typical C2 enterprise, but agreement on this concept (ala the Open Systems Interconnection 7-layer Reference Model of communications systems) would facilitate greater understanding of C2 enterprise constructs. Table 1 shows a candidate set of C2 scales and associated examples of metrics that could be collected at each scale.

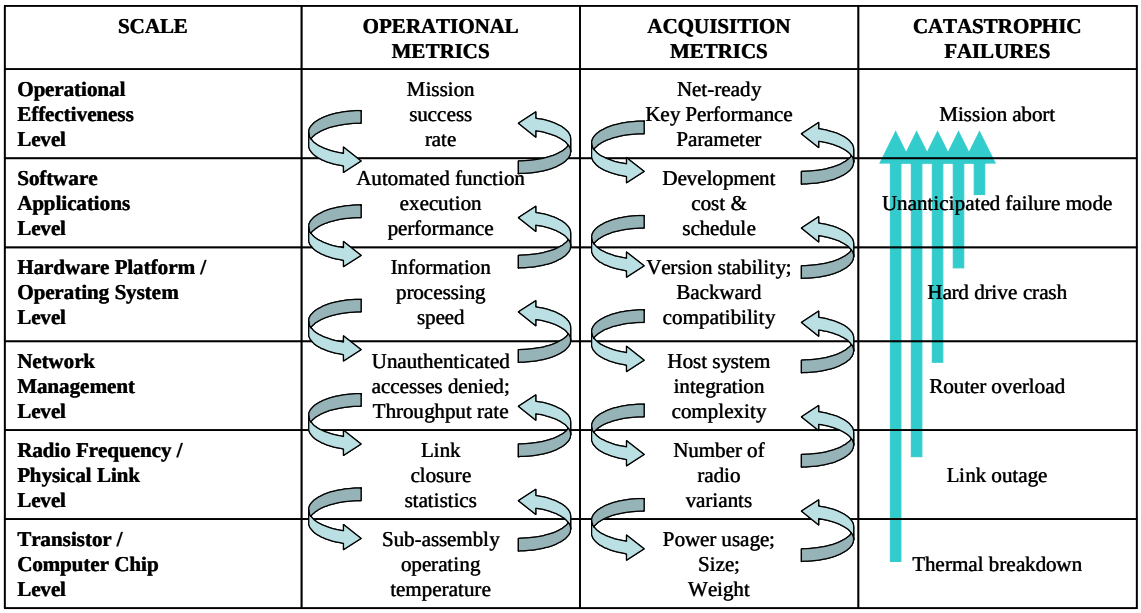

Table 1. Multi-Scale C2 Metrics Relationships and Failure Mode Impacts

It is postulated that most metrics will only map clearly one scale higher or lower than the one at which they can be collected, simulated or estimated. This may be, in fact, why some traditional mappings of MOPs to MOEs have been so difficult to understand intuitively. Mappings that span more than two of the scales in Table 1 might be very difficult to trace. Also, it might be impossible to usefully decompose operational effects into a unique set of detailed metrics at lower scales/resolution, since there are likely multiple causes for many observable effects.

A potential implication is that performance metrics at the first scale down from the operational effectiveness scale might be the most important to capture from an EA&A perspective. Another possible implication is that some lower level measurements might not be worth collecting at all, or at least only in very stressing circumstances. However, as indicated in the last column of Table 1, some lower scale conditions may transcend many others to have major impacts at even the highest scale. This implies that there is a need to identify catastrophic or cascading failure combinations that can ripple up to affect mission execution. There will likely also be a need to identify combinations of lower scale situations that enable significantly enhanced operating conditions. This could be another critical application of EA&A.

3.2 Early and Continuous Operational Involvement

Warfighters are often overloaded just trying to cope with the operational demands of each day in the field. When C2 operators have been extracted from deployed locations to participate in forward looking wargames and exercises, many have experienced the unfortunate circumstance of trying to do today's jobs in a next generation environment, instead of helping evolve future requirements, concepts of operation or concepts of employment. It is difficult, without sufficient time and training, to expect operational personnel to be able to properly critique new capabilities.

An enabler for early operational involvement in EA&A is to reduce the need for extensive training, effectively lowering the bar to effective participation in wargames, experiments and operational evaluations. Use of familiar or uncomplicated user interfaces, especially for new or initial capabilities, will permit the operational personnel to focus on the evaluation of the capability by hiding the complexity of the applications.

Another key to enabling early operational assessment in the acquisition process is to support remote participation in an interactive manner, including capitalizing on significant DoD investments in training systems to support acquisition activities. There are entire networks of active duty and recently retired personnel that could be tapped for participation in loosely structured, on-going activities to assess proposed enhancements to capabilities in the field. If personnel at any of a number of CONUS locations could log onto periodic, widely-announced evaluation activities at their convenience, the likelihood of a wide range of inputs over a period of time would be substantially increased. The commercial internet gaming industry has been particularly successful in this area, permitting thousands of simultaneous on-line users to role play in highly realistic, real-time, distributed combat simulations.

With respect to test, early involvement in development activities by any of the means cited above will begin to get operators more familiar with evaluation and assessment within a C2 enterprise. The operators can then help identify and focus on critical test issues to enable more effective achievement of test objectives. This can also serve to help establish confidence in test results as well as permit some difficult to test situations, especially those requirements related to operational availability, which can only be tested over long durations, to be better addressed.

One important component to enable continuous operational assessments within a C2 enterprise is the existence of operational scenarios and use cases. However, at the enterprise scale, it is much less important to "get it right" with any particular scenario than it is to devise ways to understand and characterize the "fitness" of the enterprise through constant exposure to diversity. EA&A at the C2 enterprise scale will certainly require injection of pieces of scenarios and use cases for increased realism, but the emphasis must be on more

generic, highly-flexible representations of wide ranges of employment options, from austere to robust, with typical uses for stakeholder systems incorporated into the mix. Repeated exposure of the C2 enterprise to complexity is critical to effectively characterize the fitness of the enterprise, especially its ability to adapt to stressing and/or unforeseen circumstances. Practically, this can be accomplished via injection of a wide range of operating conditions (as implemented in scenarios and use case vignettes) into on-line operational situations if those situations are not regularly occurring, such as major attacks by hostile forces. This analytical practice will not only enable characterization of the fitness of the enterprise to day-to-day situations, but to stressing situations as well.

Combined Developmental/Operational Test (DT/OT) events and Operational Assessments are starting to replace the separate DT and OT event paradigm. EA&A will require the extrapolation of this trend to an even greater degree. The morphing of traditional DT and OT events (often one-time activities) to a more periodic (and ultimately nearly continuous) set of Operational Assessments can occur over a relatively short time with the right perspective.

3.3 Lightweight, Portable System Representations

Despite the best efforts of a entire program or project team, it is not possible to identify and unambiguously state all of the requirements of a C2 system in a specification prior to the awarding of contract, due to the inherent complexity of C2 systems. At the enterprise scale, with dependencies among many programs needed to provide important capabilities to the warfighter, it is critical to develop effective and efficient mechanisms for collaboration among key stakeholder programs within the enterprise. Some analytical methodology must be in place to deal with requirements uncertainty.

Experimenting in novel ways by using "lightweight and portable" representations of C2 systems that can be rapidly accessed by the development and test environments of peer systems is highly desirable. Such a capability would provide opportunities to understand issues and identify opportunities for collaboration as early as possible in program acquisition and fielding schedules without the need to synchronize activities of different programs, which is practically impossible. In order to make this work, the integration times and annual costs must be kept to a minimum. Large, highly detailed models with complex interface requirements and extensive re-hosting issues squelch opportunities for collaboration. Early, small footprint models or prototypes of a system can give other programs insight into the evolving functionality of peer systems.

Such lightweight, portable representations are very appropriate for certain classes of programs, including sensor systems and communications systems. For C2 capabilities with large operator populations such as an entire intelligence processing center or an air

operations center, the representations would likely be constructed to capture the salient characteristics of specific web services. For examination of future enhancements within a large C2 node, the insertion of lightweight models of specific, proposed capabilities into the operating environment might be a cost effective and efficient way to rapidly evaluate the potential of proposed functionality.

From a methodology perspective, programs could develop and post lightweight representations of emerging capabilities to make them available to other programs without having to understand in advance which programs might want to investigate or take advantage of these new functions. Many of the reviewing programs could quickly discover what any other program is implementing or planning to implement. This method of interaction could lead to new opportunities for collaboration.

3.4 Developmental Versions Available for Assessment

It will be necessary to expose users/consumers of information and services (operational personnel and software applications) to both the diversity of other peers and the novelty of emerging capabilities. The aspect of novelty is a fundamentally distinguishing characteristic from distributed T&E environments and system integration lab networks. Traditionally, only official, released versions of software applications are eligible to be used in test or integration events. Experimental venues, while making use of early version of capabilities, have neither the persistence of an EA&A environment nor the breadth of scope to encompass an enterprise perspective.

Having access to the developmental versions of C2 applications within an EA&A environment might ultimately enable the evolution of an entirely new business model for the acquisition of future DoD C2 capabilities. With the likely possibility of numerous web services being developed with overlapping functionalities, it will be impractical to continually dictate which are "preferred" or "mandated" services. An EA&A environment could lead to a highly competitive situation where emerging net-centric web services are posted in an operationally realistic evaluation arena and users migrate to those that best satisfy their needs. Those services that are widely used (or are needed by high-profile users) would thrive and receive additional resources for evolution, while those that are seldom used would be left to wither.

Innovation within a C2 enterprise is critical because the requirements imposed on the enterprise are constantly morphing, and the C2 enterprise must be able to leverage all available options to be able to handle new situations as effectively as possible. Requirements can change quite dramatically and quickly, as was demonstrated by the radical impacts of the 9/11 terrorist attacks on homeland security requirements. Thus, there needs to be a set of solution spaces constantly under evaluation for potential benefit in future applications.

Perpetual experimentation is critical to enabling this innovation to occur within an enterprise. Requirements identification must become more flexible to enable better responsiveness and anticipation of key future needs.

As the C2 enterprise evolves, especially as the DoD comes to rely more heavily on distributed networks for communications and service access, vulnerability assessment will become more and more critical. The Government needs a solid understanding of the inherent vulnerabilities of deployed and developmental DoD network-centric capabilities. Since these capabilities are being incrementally fielded and/or fielded in potentially wildly different configurations in various locations around the world, it will be necessary to constantly assess military networks for many types of vulnerabilities. Once network vulnerabilities are identified, the Government will need to sponsor parallel activities specifically designed to assess their severity and to experiment with potential solutions. It would be highly desirable to have teams of personnel attempting to thwart proposed capabilities and working this cycle prior to deployment of operational networks. This practice could drive innovation up front, rather than relegating it to a more reactive activity.

Rapid software prototyping has provided an opportunity to look at innovative technologies and novel approaches much earlier in acquisition cycles of programs than ever before. While not intended to be robust (in any of a number of aspects), rapid software prototypes have the advantage of being able to convey complex concepts inherent in new technologies to their potential users quickly through experiential exposure, vice through detailed technical explanations. This also allows the users to get an idea of the potential of specific technologies to address operational needs or desires without the heavy investments of funding and time needed to transform research work into operationally fieldable software in order to obtain feedback.

There are two principal types of innovation, revolutionary and evolutionary, as discussed in (Johansson 2004). Evolutionary innovation is the normally occurring type and would be expected to occur even if no synthetic environment existed for EA&A. For revolutionary innovation to occur, there needs to be opportunities for very different types of agents to interact. The exposure of existing and emerging capabilities to the C2 enterprise environment could encourage revolutionary innovation, leading to significant increases in capability.

3.5 Minimal Infrastructure

In order to support assessment that enables innovative activities to progress while implementation decisions are being made, either a replication of the operating environment or access to the operating environment would be required. For some systems, this can be quite practical, as evidenced by the existence of many program testbeds at Government and

contractor locations. However, attempts to replicate the detail inherent in significant portions of operating environments, even for a single mission area (e.g., missile defense) inevitably begin to accumulate heavy logistical requirements (hardware, software, facilities, networks, etc.) and often come with high levels of initial investment and large recurring costs.

An important enabler for continuous operational assessment will be the communications infrastructure. Currently, there is a mix of connectivity available within the DoD, with a wide variety of bandwidths, costs, security levels and contention for use. From a C2 enterprise perspective, the key is to begin pulling together distributed programs with vested interests into loose collaborative frameworks to address critical operational issues with minimal recurring communications infrastructure costs. The approach of creating a huge, generic acquisition infrastructure, which has been tried several times in the past, often becomes costly to maintain and suffers from lack of a long-term advocate or set of advocates, especially when the infrastructure ceases to be new and begins to need significant upgrades. Establishing a small, high-use, core community of interest network that can effectively leverage existing connectivity within the DoD and/or short-term commercial leased circuits will provide both necessary connectivity among key stakeholders, as well as flexibility for future endeavors with other partner organizations within the enterprise.

Some ways to avoid these issues include loosely linking existing development environments among programs as well as having the ability to switch from on-line operations to off-line experimentation while taking advantage of selected imaging of local operational information exchanges (versus developing these databases). Some care needs to be taken to ensure that information that could be published back into operational databases is either filtered, tagged, or held locally to avoid operational complications.

3.6 Flexible M&S, OITL and HWIL

At the enterprise scale, it will be impossible to predict which critical issues will need to be addressed in which particular order (or in parallel). Therefore, the development of a flexible and extensible analytical framework is the most important consideration. Pursuing a goal of operational breadth first, then technical depth only on an as-needed basis will provide capability earlier and permit evolution of that capability over time that will be tailored to its true intended use.

Many large-scale simulations, and especially federations of simulations, have experienced run time performance issues as the fidelity within models increases over time and/or additional higher fidelity models have been added to the initial federation. High fidelity models (especially at the system level) will have a significant analytical role. However, for maximum flexibility at the mission effectiveness scale, it will be critical to establish analysis methodologies that can capture results of high fidelity models in effects-

based models.

An example of a large federation that has persisted over time is the Joint Training Confederation, which has stayed focused on supporting a particular user community whose stakeholders all have maintained interest and support. A key to the success of this long-standing capability is that this federation was not pulled together to support an event and then subsequently dismantled, only to be reconstructed in some variant configuration at a later date. It addresses enterprise training issues even today. There are other examples of long-term OITL successes within the training arena, such as the Air Force Distributed Mission Operations program to train pilots in cockpit simulators, reducing the amount of expensive flying hours required to certify pilots. However, the success of these M&S efforts has depended heavily on the single use paradigm and the inherent stability of the training infrastructure from year to year. EA&A will not have the luxury of dedicated users and single source funding.

The real utility of a loose federation of C2 EA&A capabilities would be to analyze the performance, emergent behavior and characterize the fitness of enterprise capabilities. In order to get at these issues, it is critical that the M&S, OITL and HWIL be flexible and capable of looking at a wide variety of issues. Analytical depth should be selectable in a "plug and play" manner used in concert with a common core capability, such that only the aspects of the C2 enterprise relevant to the issue at hand are part of an analysis infrastructure.

C2 HWIL labs run real equipment with live operators in real time and produce information in operational formats. As we move to an IP-based GIG concept, this will effectively lower a key barrier to M&S interoperability because M&S developers will need to pay less attention to the myriad, constantly changing, often misinterpreted, almost never fully implemented Joint message standards for various tactical data links. Today, for a C2 HWIL capability to talk to a simulation, operational messages are usually translated into Distributed Interactive Simulation Protocol Data Units. From an EA&A perspective, the M&S assets must be able to interoperate with HWIL using operational information standards (i.e., act like a real system or web service).

3.7 In-Line, Continuous Performance Monitoring and Selective Forensics

As more work is dedicated toward defining and understanding the relationships among the various scales of C2, it will become increasingly apparent that much of what we are able to easily measure and collect today in tests and experiments will not be useful for EA&A purposes. In order to gain insights into issues at the enterprise scale, it will be necessary to identify and capture critical performance measurements automatically, routinely and on as much of a non-interference basis as possible.

The first step in this process will be to accomplish the collection of this information in such a manner that it has little or no impact on C2 application execution. Today, we routinely insert third-party hardware or software "probes" into our infrastructure to detect what we perceive as important events. One result of these intrusions is a perturbation of the actual flow of information itself, including generating additional data traffic, creating other ripple effects within the network. Another result is the problem of trying to make the logical connection between measurements and situations that are only indirectly related to these measurements. Also, information is often collected "downstream" from where it is generated, having been manipulated along the way in some manner. Data that can be automatically archived where it is produced (within each C2 application) and collected either later or off-line, in an operational sense, for analysis is highly preferred.

The second step will be to develop an analysis capability to permit forensic investigation of problems (or opportunities). As operations proceed normally, some automated statistics generation over an extended period of time would serve to characterize the normal operating ranges of component systems and capabilities, probably requiring the development of some new tools or augmentation of existing tools. When problems (or new opportunities) are observed at the mission effectiveness scale, forensic analysis would then be required.

The third step will be to identify the sets of critical situations, states, activities, parameters, etc., that contribute to noticeable impacts on mission performance, either positive or negative. Changes in trends, performance metrics, and operational architecture, as well as coincidental circumstances would be evaluated as potential causes of mission impacts. Key to this activity will be the establishment of "tripwire" values for certain metrics that are suspected of causing changes to occur to mission effectiveness. Over time, this list will be tailored in one way or another. For example, it might only be necessary to collect certain information when specific thresholds are reached or when other indicators suggest that other types of information are needed to diagnose a problem. The only time that information about performance should compete with operational traffic is when alerts are generated. Otherwise, the architecture should accommodate off-line data collection, analysis and assessment. This analysis would require a toolset that is not yet fully developed and would likely require additional study to define.

Finally, the results of this analysis and assessment must be made available in a digestible form to the key decision makers. Summary performance parameters must be collected by the applications themselves and made available off-line for analytical purposes. The increasing, distributed development of C2 web services across the enterprise at unpredictable intervals will drive a need to stay current with emerging capabilities within a SOA framework. Service orchestration issues will need constant reassessment as different ways of accomplishing mission tasks are uncovered and understood. The net result will be the development of insights and characterizations of C2 capability robustness and the

recognition of critical underlying situations that must be watched closely as they emerge either slowly or suddenly. This information could become critical in understanding whether or not complex systems are adhering to fundamental implementation and standards guidance. Thus, EA&A could serve a vehicle for policy compliance within the C2 enterprise.

4 Role of the Government

In recent years, the role of major defense contractors, in terms of acquisition responsibilities, has steadily increased. This has been implemented in the form of Total System Performance Responsibility, various types of integration contract awards, and the scoping of overarching C2 contracts (e.g., Army Future Combat System). In parallel, Government engineering talent has been lost through retirements and repeated reductions to both military and civilian manning levels at CONUS bases. With this situation as a backdrop, both the Government and the contractors are experiencing difficulties working complex C2 problems in today's acquisition environment. Historically, the Government has had a stronger engineering presence to be able to have a greater influence on the course of C2 acquisition activities. Effective EA&A will require the *development of very knowledgeable Government teams* able to have unique insights into the technical and programmatic issues of the acquisition *often before the contractors do because they have the tools at their disposal to perform system analysis and assessment independently from the contractors*. This will directly improve the ability of program management to avert issues.

It will be critical for the Government to maintain experienced cross-domain teams to work enterprise issues that span programs and capabilities. It will also be important for the Government teams to have access to tools and virtual environments that can permit examination of critical issues at this scale. Instead of imposing strict control over models and virtual environments, as is routinely done today, a C2 enterprise analysis Government team must possess a very flexible and fluid C2 enterprise toolset. The exact composition of the Government teams must be able to vary based on need, and the makeup of the teams will have to include operational personnel. A C2 Government analysis and assessment team (e.g., for a particular mission area), as well as the associated synthetic environment, must persist past the award of contracts for individual programs. A persistent Government enterprise assessment team must have specific analytical roles during all phases of current and future C2 contracts.

A possible methodology for addressing C2 EA&A is to "hire a contractor" to do this thinking, implementation and execution, much like the Lead System Integrator model for program execution. While input from industry is essential, this overall approach appears problematic for a number of reasons. For example, despite the consolidation within the defense industry, individual contractors still only understand a portion of the C2 enterprise, and they often exhibit difficulty sharing information internally across projects within their contract portfolios. The Government needs to have the ability to look beyond the sight lines of any particular defense contractor, no matter how large or distributed. However, contractors are increasingly trying to take advantage of the knowledge that they have gained

as companies have merged to the point that they have begun to market their integration expertise. System integration experience provides opportunities for depth of understanding of a particular domain or mission area. These companies are in a great position to provide the necessary depth to the analysis infrastructure for the systems that they develop, as needed.

Certainly, a role for the Government is to advocate for key stakeholder participation and, ultimately, even wider participation to achieve maximum effectiveness. MITRE is in a unique position to provide important technical support to Government C2 enterprise analysis and assessment activities into the future by identifying opportunities for collaboration and helping to bring programs from across the Services together. Technical excellence and breadth brought to bear on such a Government team will pay dividends. The Government must also advocate for proper resource allocation.

4.1 MITRE's Role

As more work is MITRE has a key role to play in the evolution of EA&A, particularly in the following areas:

- Vision
- Education
- Technology development and application
- Process implementation and refinement

MITRE is in a position to develop the vision for EA&A, articulate it to important stakeholders within the DoD, document the vision and then make it available to a much wider audience.

From an educational perspective, MITRE could play a role in the education of customer program personnel, especially those personnel involved in T&E, Contracts and Systems Engineering. Internally, training could be arranged for Chief Engineers, Project Directors and Project Leaders.

Internal technology ideas could be pursued by way of new MSR and MOIE proposals. MITRE support to the MITRE Systems Engineering Process Office and Electronic Systems Center's Chief Engineer Office (ESC/EN) provide opportunities for EA&A process implementation and refinement via application to work program areas. There is a unique opportunity for MITRE leadership in this area.

From a C2 system acquisition perspective, the key players in enterprise analysis and assessment are at the technical staff level and at the project manager level. Each category of personnel should have a vested interest in staking out roles in the analysis and assessment

arena. What are those roles and why are they important?

First, from the viewpoint of a project manager, as someone who has direct contact with a customer (or set of customers), a primary goal is achieving a high level of overall customer/sponsor satisfaction with respect to the quality of support and the products that are delivered to the users. As C2 systems become more functionally complex to address the emerging sophistication of threats, and as they move toward net-centric operations using service oriented architectures, it is becoming increasingly difficult to demonstrate the performance of any individual system to a customer or sponsor without the need to show added value in the proper context as well as appropriate interoperation with peer systems. In fact, increasingly, such peer systems will not just be those fielded by a service (e.g., the Air Force), but by other military Services as the focus of military operations shifts to the employment of truly Joint capabilities. Therefore, Government Program Managers and MITRE project managers will need to address how to establish collaborative approaches to demonstrating the functionality and utility of developed capabilities with other partners in a particular community of interest (COI), at the very least. Thus, system assessment and evaluation approaches must consider significant enterprise partnerships right from the start of planning opportunities.

Second, from the viewpoint of technical staff supporting a particular project or program, the idea of C2 analysis and assessment at the enterprise level can seem overwhelming and even out of scope from an individual tasking perspective. However, it is often at the technical staff level that opportunities for collaboration among systems and their developers can be identified and solidified. While there might be an intent for a group of programs or projects (even as few as two) to work together to demonstrate progress toward achieving a new or enhanced capability for a set of users, until the technical staff from the different programs or projects get together to "peel back the onion" to uncover realistic methods of interaction, significant progress cannot be made. Ultimately, a sufficient amount of this type of collaboration among multiple partners can lead, through analysis, to the uncovering of potentially more effective and efficient means of interoperation at the enterprise level. In turn, this can lead to opportunities to validate proposed approaches via the prototyping of new technical frameworks by technical staff. This crucial step, from pair-wise interoperation to a realization of more general concepts for flexibly providing capabilities, enables desirable enterprise level effects to be produced. Another important contribution at the technical staff level is the development of appropriate metrics for the customer, Service, COI, etc., to measure the progress of fielding C2 capabilities. Only at the technical staff level can such metrics be established, evolved and quantified. Integration of operational users in the design and requirements definition process is critical to acquisition success.

Another consideration is the skill set of required within a Government team of personnel formed to address C2 enterprise analysis and assessment. MITRE is in a unique position to

provide support for C2 enterprise analysis activities because of its breadth of programs supported and its DoD Federally Funded Research and Development Center responsibilities. Support for Government C2 EA&A requires the kind of impartial perspective and domain knowledge that MITRE is uniquely positioned to provide. The overall skill set that MITRE could offer would need to include the following qualities within the team members:

- Big picture perspective
- Analytically oriented
- Technically competent within the COI to be assessed
- Programmatically astute across multiple programs
- Operationally knowledgeable on C2 issues
- Comfortable working in collaborative environments
- M&S background or experience, including distributed simulation
- Aware of applicable technologies

5 Next Steps

The vision for C2 EA&A is that users, developers, program managers, engineering staff, contractors and decision-makers within the DoD have a stake in C2 EA&A. The following are some key next steps to enable progress in the EA&A arena. First, it will be critical to enlist the support of a few forward-leaning C2 programs to collaborate on a pilot effort. It will be necessary to identify stakeholder programs with shared capability dependencies. In order to facilitate this, a key early effort will be to develop an implementation guide with practical suggestions for how to proceed given the constraints of existing programs. Such a "toolkit" will enable staff and management on a particular program to understand how to get started down the EA&A path in a practical manner. It should include suggestions for a variety of concerns, such as keeping infrastructure costs to a minimum, for example. In this case, the use of leased phone lines for connectivity might be a good early strategy.

Second, it will be important to leverage the lessons of DoD M&S-based training programs and commercial computer-based gaming over internet. These activities have focused on breaking down barriers to user participation. They have also been able to make strong connections with user needs and interests.

Third, it will be critical to emphasize EA&A as a new activity, not a new program. The education of key stakeholders to make them aware of the coming need for EA&A as well as their roles in the process will be fundamental to the success of EA&A activities.

Finally, it will be important to invest in critical technologies to enable proper implementation of C2 EA&A. There are a number of areas requiring further investigation to help enable the implementation of C2 EA&A. A candidate list of these areas is as follows:

- Multi-scale analysis
  - How do C2 performance metrics collected at a lower scale relate to those collected at the mission effectiveness scale? How can we identify the sets of conditions producing threshold "tripwires" that, when crossed, produce changes in mission performance? How should we characterize these thresholds?
- Minimal, parallel EA&A infrastructure
  - What type of distributed infrastructure will allow collaborative investigation of C2 enterprise issues without bankrupting programs? Can this be used for incremental fielding of new C2 capabilities (seamless off-line to on-line transitions)?
- Lightweight, portable system representations
  - How can programs assure themselves that they have appropriate representations of stakeholder/partner system capabilities to properly perform independent or collaborative analyses?

- GIG and/or Airborne Network modeling/representation
  - What type of representation is required of operational communications infrastructure capabilities to permit robust EA&A by individual programs or groups of programs?
- Embedded analysis capabilities
  - How should analysis capabilities be embedded within C2 systems to permit EA&A to occur continuously, remotely and without interference to mission execution? Can security issues be addressed in such a manner?
- SOA M&S approaches
  - How should a SOA implementation be modeled? Do commercial modeling initiatives Business Process Execution Language, Business Process Modeling Language, etc.) or MITRE initiatives (Modeling Environment for SOA Analysis, etc.) show promise for EA&A needs?
- Executable architectures
  - How can voluminous architecture information collected by many programs be effectively used for real-time EA&A? Can current attempts to animate architecture tools scale to EA&A?
- Enterprise scalability analysis techniques
  - How can system capabilities be robustly assessed for the ability to scale to enterprise use? How can the viability of Service Level Agreements for DoD applications be assessed?
- Contracting mechanisms to enable continuous operational assessments
  - How can novel approaches to EA&A be incorporated in future C2 development contracts?

The modeling capabilities commercially available today are only beginning to address ways of analyzing enterprises based on a SOA construct and have focused to date on lower level metrics and more static than dynamic kinds of analysis. Issues such as web service orchestration for C2 applications and end-to-end mission performance impacts of transitioning from dedicated, message-based, tactical data links to GIG communications relying on IP routing for data and C2 information distribution have not yet been worked from an analysis tool perspective. An appropriate M&S infrastructure approach needs definition and prototyping to permit useful analysis to occur at the C2 enterprise level.

As mentioned earlier, the notion of executable architectures that can be useful at the enterprise level for analysis requires effort dedicated toward addressing linkages to M&S tools and analysis frameworks. Some effort has been started by the Air Force in this area, but more work needs to be done.

The notion of lightweight, portable representations for specific C2 systems operating within an enterprise context must be further explored. In particular, such representations

would be appropriate for sensor and communications systems and should be relatively inexpensive to develop (in fact, this would be a requirement). Some rapid software prototyping needs to be attempted for a candidate C2 system to validate the assumptions regarding the degree of utility of this approach for increasing collaboration opportunities across the enterprise.

Also, the notion of continuous operational assessments in support of T&E and other program objectives has implications from a contractual perspective. This concept might need to be inserted into future contracts or modifications to existing contracts through creative means until the benefits of such an approach become clear. If the benefits become tangible and well-understood, some standardization of contracting norms or policy decisions might make future implementations of this concept more robust or explicit.

5.1 Practical Considerations.

In the process of performing EA&A, there will be a number of considerations that will come into play. In some instances, these will be programmatic in nature, policy or guidance related, or with regards to the limitations of current technology.

There will likely be certain test and certification requirements within the C2 enterprise that will be independent of how the overarching C2 EA&A evolves. Those certifications that are required to ensure human safety or to protect against the possibility of litigation, for example, will be necessary and must be included within an enterprise perspective on assessment. These certifications must be periodically checked as the enterprise evolves, however, the frequency and scope of these checks must be determined over the course of time. With experience, the Government will better be able to realize how to ensure that safety, legal and other such issues are properly addressed and maintained as changes continue to propagate through the C2 enterprise during its evolution. For the near term, however, the approved, existing methodologies for certifications of various types will need to be accommodated even though they might not align philosophically with emerging C2 EA&A approaches. In the near term, the goal would be to look for ways to use results generated in the different evaluation environments to support mutual objectives. In the far term, the routine incorporation of safety, litigation prevention, security, etc., processes and procedures into more continuous enterprise evaluations could actually reduce the overall risk of problem occurrences due to the fact that these certification checks would be performed much more often (or even automatically) as changes are introduced.

Configuration management (CM) and model verification, validation and accreditation (VV&A) are activities that must accompany the execution of any enterprise capability analysis. Standard software CM processes should be completely adequate for tracking system versions as well as the associated software toolsets.

VV&A is another matter entirely. The often unrealistic VV&A requirements derived from the existing DoD policies for M&S are an impediment to M&S activities in support of EA&A, especially for analysis of future systems and enterprise operations (or existing systems in future operating environments), where these systems and capabilities do not yet exist. In such situations, modeled representations cannot be validated. Even current systems are normally fielded in multiple variants that undergo constant evolution, making any snapshot modeled representation and accompanying model VV&A only valid for a specific system variant at a specific point in time, at best.

When attempting to identify and characterize fitness and emergent behaviors within a C2 enterprise, it is more important to have some reasonable representation of each crucial component (with appropriate loading considered) than to have a few highly detailed models that represent very specific instances of systems. A goal of "endorsed" EA&A activities can only be achieved if traditional model fidelity arguments are redirected instead toward more productive discussions, such as attempting to identify reasonable characterizations of the behavior of component systems and capabilities to satisfy the intended analytical purpose. This is a significant break from the current VV&A processes and guidance for M&S for systems. Although rigorous standards exist at the system/sub-system level within the DoD (with various Service implementations and guidance), the practical implementation of model VV&A activities on every program is always tailored to fit schedule, budget and technical considerations, such that no program ever implements the entire specified process. The law of diminishing returns applies quickly to current model VV&A practices. Realistic policies must be developed to address VV&A issues at the enterprise scale.

Finally, there is little or no guidance available within the DoD regarding C2 EA&A. Most of the existing policy and guidance is aimed at the system level (e.g., DoD 5000 series, Joint Capabilities Integration and Development System, etc.). In addition, there is no documented experience in performing EA&A from which to derive lessons learned. The practical impact of this fact is that there will be resistance to embarking upon a new activity for many programs. Funding for some of the precursor efforts will be a challenge. The lack of guidance in this area is part of the rationale for developing the vision for future C2 EA&A contained in this paper. It is intended that early awareness on the part of a few key programs could spur some initial activity in the EA&A domain.

6 Summary

The vision for C2 EA&A is that users, developers, program managers, engineering staff, contractors and decision-makers within the DoD have a stake in C2 EA&A. An affordable, flexible, multi-scale analysis capability will:

- Encourage continuous experimentation and virtual gaming, leading to rapid innovation
- Examine broad trade spaces of potential operating conditions to ensure robustness
- Create stakeholder understanding of expected C2 behaviors to evolve concepts of operation and positively influence the evolution of C2

Lightweight representations of emerging C2 capabilities can be published to readily-accessible servers and available to authenticated users for assessment when and where these evaluators deem necessary. On-line/off-line context switching for operators will enable users to easily switch from their "day jobs" or training activities over to an environment that looks very close to their operational environment, except that the applications being exercised are next-generation C2 applications. The evaluation environment will use selectively imaged operational databases, augmented with simulated events to permit "apples-to-apples" comparisons of even such offerings as competing web services and service orchestration technologies.

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Glossary

C2	Command and Control
COI	Community Of Interest
CM	Configuration Management
CONUS	Continental United States
DoD	Department of Defense
DT	Developmental Testing
EA&A	Enterprise Analysis and Assessment
GIG	Global Information Grid
HWIL	Hardware-in-the-loop
IP	Internet Protocol
IT	Information Technology
M&S	Modeling and Simulation
MOE	Measure Of Effectiveness
MOP	Measure Of Performance
NR-KPP	Net-Ready Key Performance Parameter
OITL	Operator-In-The-Loop
OT	Operational Testing
SOA	Service Oriented Architecture
T&E	Test and Evaluation
VV&A	Verification, Validation and Accreditation