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Challenges and Opportunities for Simulation Systems Introduced by Rapidly Evolving Mission Command Information Systems Standards

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ABSTRACT

Attaining command and control (C2) and simulation interoperability is an elusive goal due to the asynchronous nature of system development environment of those systems. Modeling and simulation (M&S) systems and federations often rely on relatively longstanding interface standards and data practices from the Mission Command (MC) community for test, training, and operations. MC is rapidly upgrading their standards and practices to be more dynamic and consistent with modern web-based technology. For example, M&S has long relied on Data Dissemination Services (DDS) as a means to stimulate MC systems. As MC moves to “big data” solutions such as Unified Data (UD), it is anticipated that this will cause non-trivial adjustments in interoperability related processes and potential issues of trust and increased cyber-related vulnerabilities. Similarly, M&S systems rely on fixed address books for initialization while the introduction of Warfighter Initialization Tool (WIT) technologies in MC systems allow for more dynamic address books. Initialization of M&S systems may need to make substantial adjustments in response to this new technology. This paper explores the DDS and WIT use cases, the impacts on interoperability, and how the two communities may better coordinate in order to support the warfighter and mitigate trust and potential cyber concerns.

1. Introduction

The interface between Command and Control (C2) systems and simulation systems has long been characterized by a focus on interoperability. This paradigm of interoperability is challenged by the rate of increasing complexity in the operational environment itself. The C2 world must keep pace with this complexity. If the benefits of the combined capabilities of C2 and simulation are to continue to be realized, the simulation systems and the interface must also keep pace with this complexity.

1.1. Operational Complexity Backdrop by the Numbers

It is straightforward to make the case the operational environment is increasing in complexity. C2 systems must deal with increasing amounts of data, which may result in more complex interchanges and interfaces. Consider the following statement from General Martin Dempsey in 2012:

> *"Modern C2 systems transport and deliver information in quantities that can easily overwhelm the commander." (1)*

The case can also easily be made that increasing operational environment complexity is driving a consequent desire to employ greater C2 agility. The C2 Agility Handbook states:

> *"This operational complexity has been widely recognized by the senior leadership of the Department of Defense (DoD), and there have been repeated calls to increase the agility of US forces." (2)*

Agility is defined as "the capability to successfully effect, cope with and/or exploit changes in circumstances." (3) Can the marriage of simulations with C2 systems help or make matters worse with respect to agility? That question may remain unanswered for at least the near term, but can simulations and C2 systems even keep pace with one another? In order to support a simulation-based Mission Command[1] capability such as Mission Planning, the data flow between C2 systems and simulations must be very efficient. Both communities are practitioners of the use of standards, but are they the same standards or even compatible standards? In this paper we examine technology areas in which at least one C2 system provider, the U.S. Army Mission Command system developer, is examining the use of various emerging commercial and open source standards to meet the challenges of operational complexity. We discuss what impacts these technologies may have on the simulation community.

Consider any number of factors, technological, political, and even cultural, that contribute to the complexity of the operational environment. The ability to develop plans and orders,

[1] See ADP 5.0, "The Operations Process" (19) ADP 6.0, "Mission Command" (18) for descriptions of U.S. Army Mission Command and operations.

or otherwise simply make informed decisions - key aspects of C2 - in such an environment will be aided by the application of agile principles.

Table 1 Open Source Measures of Operational Environment Complexity

Metric	Metric Value	C2 / Simulation Implication	Sources
Number of conflicts worldwide	• 34 (CFR) • ~50 (Wikipedia) • ~70 (Conflictmap)	• Geospatial • Cultural • OOB / Equipment • Languages • C2 systems	• Council on Foreign Relations (CFR) (4) • Wikipedia • Conflictmap.org (5)
Number of mobile devices worldwide (as a percentage of world population)	• >100% (i.e., > 7.1 billion)	• Digital data increase • Address space increase	Cisco white paper (6)
Number of formal worldwide military alliances	• ~ 28	• Force representation • C2 systems and tactical data	Wikipedia (7)

Other measures that might be of interest are the following:

- Number of CPUs worldwide (and the rate of growth in this number)
- Number of satellites worldwide[2]
- Number of routers and switches worldwide (and the rate of growth)
- Age of tactical data links (and their percentage reserve capacity)
- Number of data standards (military, commercial, open source) in tactical C2
- Number of unmanned surface (as well as air, space and subsurface) systems worldwide
- Advances in Artificial Intelligence and Human Behavior Representation[3]

Still other considerations that may be available, but may be classified or may have never been collected and analyzed:

- Capacity of tactical data links (available bandwidth)
- Number of decision points in various types of operational plans or COAs[4]
- Number of OPORDS[5] and FRAGOS[6] in a campaign

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[2] The Union of Concerned Scientists tracks over 1,200 earth satellites (16).
[3] Nick Bostrom's book *Superintelligence* (17)addresses many key parameters and predictions.
[4] Course of Action
[5] Operations Orders
[6] Fragmentary Orders

- Number of sources in intelligence fusion / COP[7] development
- Average time taken for deliberate planning / time for hasty planning
- Number of Information Exchange Requirements (IER)s in C2 systems

The point is an obvious one: operational complexity, especially in the military C2 environment, is increasing. The C2 and simulation communities of interest will be compelled to increase their understanding of this environment and thereby advance the C2 and simulation systems that must operate in it. The incorporation of certain technologies, discussed in this paper, in C2 and simulation systems both, is a step in realizing those advancements.

1.2. Thesis of the Paper

The thesis of this paper is that several factors, both operational and technological, are contributing to the evolution of C2 systems and some of these will drive C2 systems to operate in an environment that will require, or at least aspire to, a level of agility that has hitherto been unattainable. The ability to achieve this level of agility can be supported, to a degree, by the employment of simulations, but only if those simulation systems also keep pace with the increasing demands of operational complexity.

1.3. Paper Outline

This paper examines how standards in C2 are changing rapidly and how this may affect Simulation to C2 interoperability. Specifically we look at two areas: Database and Tactical messaging (Big Data); and initialization or the ubiquity and importance of internet protocol (IP) addresses for everything.

2. Background and Discussion

2.1. The Goal: Why Connect Simulations to C2?

The advantages of using simulation in support of C2, especially MDMP have been pointed out by numerous authors (8) (9) (10). Simulations have the potential to address some of the operational complexity concerns. In particular, simulations can offer multiple predictions based on detailed tactical information. Simulations can replicate real world data and use those in the predictions. These capabilities can greatly enhance the agility of C2. The case can be made that there is an analog to this idea of a C2 “virtual staff” taking shape in the commercial world with systems like Apple’s Siri and Google’s acquisition of Emu.

2.2. Why Hasn’t This Been Done Before?

Simulation systems have rarely if ever been connected to C2 systems in such a way as to put M&S in the critical path of a mission. Simulation systems have been used for

[7] Common Operating Picture

training, for test and experimentation, and for analysis. Using simulations in direct support of C2 operations is a relatively new idea (8).

2.3. Where is C2 Going?

The field of C2 itself must keep pace with technology and the increasingly complex operational environment. One way of thinking about possible new models of C2 is the concept of agility (9) and C2 Approach space. In this paradigm, the ways of looking at C2 are considered in the following three dimensional space

- Distribution of information;
- Patterns of interaction; and
- Allocation of decision rights.

This point of view challenges the notion that there is only a single, defining perspective of C2. Supplementing C2 with simulation may in fact enable a category of C2 approach in this space.

Another significant driver for the future of C2 is the concept of "network centric warfare." The U.S. DoD has begun the process of looking at mission command in the light of the ubiquity of the network as it defines network enabled mission command (NeMC). Simulation makes an appearance as a contributor in this new environment.

2.4. Can Simulation Keep Up With C2?

If the M&S and C2 communities continue along relatively uncoordinated trajectories, one of the continued challenges to be faced is that of synchronizing capability. Phenomenology in the "real world" will need to be dealt with by C2 in a manner commensurate with security consequences and therefore often in an urgent manner. Technology is sometimes the culprit of this problem, but also sometimes the solution. If it is assumed that advances in C2 will at least in part be driven by an increasingly complex operational environment, then simulations themselves will be required to look at some of the same drivers either together or in parallel with C2.

3. Two Examples: Big Data and the Internet of Everything

There are multiple examples of technology that are enabling the increasing complexity of the operational environment. In the world of Information Technology (IT), two in particular, stand out: Big Data and the Internet of Things (IOT) (12), also known as the Internet of Everything (IOE) (13).

3.1. Big Data

The concept of so-called "Big Data" has suffered in credibility through what could be argued as popular overuse as a term of art. It is nonetheless a real and viable concept that is being addressed by IT institutions and the popular media alike. The International

Telecommunications Union (ITU) in its publication "*Measuring the Information Society"* (14) provides the following understanding of big data:

> *"… usually refers to large and complex datasets, and reflects advances in technology that make it possible to capture, store and process increasing amounts of data from different data sources."*

Wikipedia is even more pointed:

> *"Big data is an all-encompassing term for any collection of data sets so large or complex that it becomes difficult to process them using traditional data processing applications."*

The exploration of all the implications of Big Data in the C2 to Simulation space is beyond the scope of this paper. The ITU publication cites five characteristics of Big Data, known as the five "vees."

Table 2 Five V's of Big Data, C2 and Simulation

Characteristic	Description (from ITU)	C2 to Simulation Implication
Velocity	Speed at which data are generated and analyzed	C2 systems will consume and generate data at high speeds; simulations, if expected to support planning or other decision support, will be required to analyze data at high speeds.
Variety	Different types of data including large amounts of unstructured data	C2 systems may not be restricted to highly structured, standardized data, but may be required to ingest data from unexpected sources and/or data from a variety of sources such as many different kinds of sensors and geographic information. Simulation systems will likewise need to accommodate this variety of data.
Value	Potential of data for socio-economic development	This characteristic should be interpreted through the lens of mission "value."
Veracity	Level of quality, accuracy, and uncertainty and data sources	The need to understand the quality and accuracy of the data for a C2 system, including the security implications, is critically important. Simulation systems will need to be concerned with correctly reflecting the accuracies and uncertainties in the C2 data.
Volume	Vast amounts of data generated through large-scale datafication and digitization of information	The volume of data itself may drive C2 systems to revisit technologies and architectures. Similarly, simulations will need to accommodate large amounts of data without overburdening the C2 systems storage and retrieval capability.

Big Data in the C2 to Simulation context may not be completely analogous to the commercial paradigm, but it will possess its own version of the five “V”characteristics. A concept referred to as Unified Data has been introduced into the MC terminology. Unified Data shares many of the characteristics of Big Data. Unified Data will be called upon to support the following:

1. Store – This includes data from longstanding MC sources such as Data Distribution Services (DDS) and other tactical data of interest to the command post (CP)
2. Enhance – Using correlation techniques and database technologies, Unified Data will be expected to use disparate sources to improve the quality of data for the Warfighter
3. Analyze – Using various analytic methods, Unified Data will need to process data against various measures, filters, and other algorithms
4. Process – Unified Data will need to support workflows and other processes
5. Secure – May need to support various classification levels
6. Operate in a Disconnected, Intermittent, Low Bandwidth (DIL) environment – In a tactical environment, unlimited access to networks may be severely limited

This Unified Data effort (see Figure 1) has been reified in a pilot effort. In this pilot effort many different types of data are brought together in a single store and enhanced to provide the warfighter greater analysis capabilities. The pilot effort is described functionally below with a specific use case.

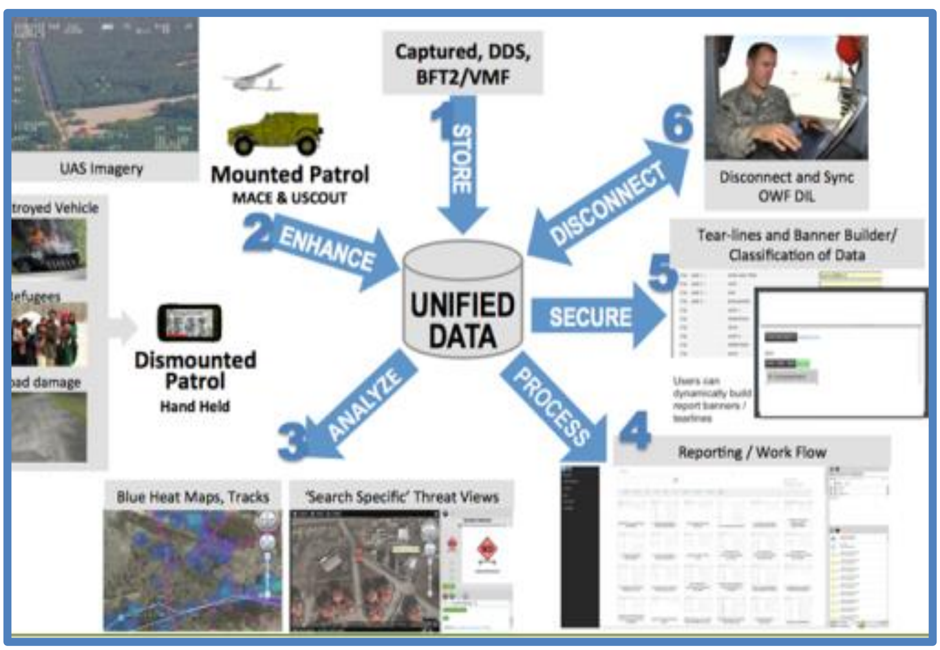

Figure 1 PM MC Unified Data pilot characteristics

The use case described shows the unified data stack ingesting position locations from an existing store, and then enhancing them with data feeds from other sources. Next a user can analyze these to perform routine functions, such as finding historical friendly positions, which typically involve correlation of a lot of different information thus reducing cognitive burden. Finally the data is processed and secured at the correct level of classification to ensure that each specific cell or attribute of data has an appropriate classification and releasability marking. Simulations will need to operate in the same environment with a functional equivalence if they are to be expected to support C2 in tactical operations.

There are several key Big Data (and therefore, Unified Data) technology enablers. One of the most significant of these is Not only Structured Query Language (NoSQL) database technology. NoSQL allows the intake of unstructured, or much less structured data, than traditional SQL database technology. It is not a replacement for highly structured, relational database technology, but can be employed alongside SQL. Another key enabler is JavaScript Object Notation (JSON). As an alternative to XML, JSON provides real-time server-to-browser communication without using a browser plugin. These technologies are also being adopted on the simulation side. Representational State Transfer (REST) protocols have also greatly enabled scalability of the web. Cloud computing also is both a product and an enabler of Big Data.

As Big Data is deployed and used in a C2 environment, appropriate provisions must be made for simulation system interfaces. A simulation system often relies on C2 Situational Awareness mechanisms for updates to the simulation database, e.g., by using a DDS feed into the simulation. These mechanisms get more robust as Big Data is leveraged to a higher degree. The context of information becomes increasingly important especially in the context of veracity.

3.2. Internet of Things

The Internet of Things (IoT) (12) is a rapidly emerging technology space that is exploiting the ability to embed internet connectivity into a great multiplicity of physical devices, not just ground and air vehicles, but components of vehicles, appliances, other household and industrial items, and even living things. At first, this may seem unrelated to the world of military C2. After all, military C2 systems operate in a secure environment, with well known “address books,” message formats, and protocols. However, the increasing ability to store, hide, and transfer information from anywhere and using anything (literally) has the potential to introduce a much larger digital picture with which C2 systems must cope. It is certain that the IoT will take advantage of the IPv6 address space of 3.4×10^{38} addresses, which according to IoT6.eu (15) will be more than sufficient to blanket the surface of the earth[8] with IP addresses. This will clearly have an impact on the concept

[8] The surface of the earth is 5.1×10^{8} km^2.

of position location information (PLI). Position location information (PLI) in the military domain corresponds to the geospatial location of a given vehicle. In the IoT, all IP addresses may provide PLI for each related device. This could allow for valuable aggregation or decomposition of what resources exist at a given geospatial location. Capabilities such as the Warfighter Initialization Tool (WIT) must in the future accommodate the potentially greatly increased address content of this environment. Similarly, simulation systems, especially those that rely on tools such as the WIT will also need to accommodate this increased complexity.

3.3. C2 to Simulation Progress and Trust

It should be obvious that if the potential of simulations interfacing to C2 devices in an “operations” mode are fully realized, issues of trust will arise. Simulations that can provide predictions and excursions of “ground truth” based on both time-stamped, PLI sensor data along with projected or planned data will certainly pose enormous challenges as well as significant opportunities for decision makers who use the hybrid systems. Addressing these challenges may require new ways of thinking about how data is transformed into information and then into knowledge, involving issues of epistemic trust, potentially encroaching on new areas of psychology and philosophy that might be called “synthetic epistemology.”

As cyberhardening of applications in C2 systems increases, there are also issues of trust in a simulation. Planned technologies in C2 systems expect to deploy continuous authentication, cell based security and other forms of protection. With the growth in devices, it becomes increasingly difficult for simulation systems to impersonate all of the “things” in the IoT that play a role in the C2 architecture. In the as soldiers play an increasing role as battlefield data collectors, there might be several devices on their bodies that relay significant information to the C2 architecture. In order to effectively simulate these, the simulation systems must take into account the trust and protection mechanisms employed.

4. Community of Practice Coordination

If the thesis of this paper is correct, the two communities, C2 and Simulation, will need to begin an even closer and more consistent coordination. This will be of critical importance if system capabilities such as the Virtual Staff are to be accomplished.

5. Summary and Conclusions

This paper has presented the case that operational complexity is driving the need for a kind of C2 agility that can be provided by a closer integration of C2 systems with simulations. C2 systems may be required to react to the operationally complex environments with available technologies (such as NoSQL) more rapidly than simulations.

Simulation systems, will therefore need to track these changes in standards and architectures and follow suit. More importantly, there is an increased need for coordination of the two communities and the establishment of a combined community of practice.

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