LIMITATIONS OF MICRO AND MACRO SOLUTIONS TO THE SIMULATION INTEROPERABILITY CHALLENGE:

AN EASE CASE STUDY

by

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To our fallen heroes and their families, may we never forget their sacrifice.

ABSTRACT

This thesis explored the history of military simulations and linked it to the current challenges of interoperability. The research illustrated the challenge of interoperability in integrating different networks, databases, standards, and interfaces and how it results in U.S. Army organizations constantly spending time and money to create and implement irreproducible Live, Virtual, and Constructive (LVC) integrating architectures to accomplish comparable tasks. Although the U.S. Army has made advancements in interoperability, it has struggled with this challenge since the early 1990s. These improvements have been inadequate due to evolving and growing needs of the user coupled with the technical complexities of interoperating legacy systems with emergent systems arising from advances in technology. To better understand the impact of the continued evolution of simulations, this paper mapped Maslow's Hierarchy of Needs with Tolk's Levels of Conceptual Interoperability Model (LCIM). This mapping illustrated a common relationship in both the Hierarchy of Needs and the LCIM model depicting that each level increases with complexity and the proceeding lower level must first be achieved prior to reaching the next. Understanding the continuum of complexity of interoperability, as requirements or needs, helped to determine why the previous funding and technical efforts have been inadequate in mitigating the interoperability challenges within U.S. Army simulations. As the U.S. Army's simulation programs continue to evolve while the military and contractor personnel turnover rate remains near constant, a method of capturing and passing on the tacit knowledge from one personnel staffing life cycle to the next must be developed in order to economically and quickly reproduce complex simulation events.

This thesis explored a potential solution to this challenge, the Executable Architecture Systems Engineering (EASE) research project managed by the U.S. Army's Simulation and Training Technology Center in the Army Research Laboratory within the Research, Development and Engineering Command. However, there are two main drawbacks to EASE; it

is still in the prototype stage and has not been fully tested and evaluated as a simulation tool within the community of practice. In order to determine if EASE has the potential to reduce the micro as well as macro interoperability, an EASE experiment was conducted as part of this thesis.

The following three alternative hypothesis were developed, tested, and accepted as a result of the research for this thesis:

H_{a1} = *Expert stakeholders believe the EASE prototype does have potential as a U.S. Army technical solution to help mitigate the M&S interoperability challenge.*

H_{a2} = *Expert stakeholders believe the EASE prototype does have potential as a U.S. Army managerial solution to help mitigate the M&S interoperability challenge.*

H_{a3} = *Expert stakeholders believe the EASE prototype does have potential as a U.S. Army knowledge management solution to help mitigate the M&S interoperability challenge.*

To conduct this experiment, eleven participants representing ten different organizations across the three M&S Domains were selected to test EASE using a modified Technology Acceptance Model (TAM) approach developed by Davis. Indexes were created from the participants' responses to include both the quality of participants and research questions. The Cronbach Alpha Test for reliability was used to test the reliability of the adapted TAM. The Wilcoxon Signed Ranked test provided the statistical analysis that formed the basis of the research; that determined the EASE project has the potential to help mitigate the interoperability challenges in the U.S. Army's M&S domains.

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CHAPTER 1: INTRODUCTION

Chapter 1 abstract:

The U.S. Army uses many types of simulations categorized as live, virtual, or constructive, referred as LVC. Simulations have proven to be valuable for analysis, research, and training tools for the U. S. Army. In addition, simulations' relatively low cost, flexibility, and proven training value, such as the use of SIMNET (Simulation Network) in preparing Soldier's for Operation Desert Storm, have caused the simulation development and application to proliferate across many U. S. Army activities. Despite the continued advances in the U.S. Military's common simulation architectures, DIS (Distributed Simulation Network), HLA (High Level Architecture), Testing and Training Enabling Architecture (TENA) and the Common Training Instrumentation Architecture (CTIA), the U.S. Army has struggled with simulation interoperability in establishing reproducible LVC integrating architectures (Davis & Anderson, Improving the Composability of Department of Defense Models and Simulations, 2003). *The interoperability challenge of integrating different networks, databases, standards, and interfaces results in the U. S. Army organizations to repeatedly spend time and money to create and implement irreproducible LVC integrating architectures to accomplish similar tasks.*

The Categories of Army Simulations: Live, Virtual, and Constructive

The U.S. Army uses many different types of simulations in order to prepare its ranks for real-world missions. A well known phrase in the Army is “All But War is Simulation” (STRICOM, 1995) and is the motto for the Program Executive Office for Simulation, Training and Instrumentation (PEO-STRI). In order to help identify the many types of simulations, the Army categorizes them into three types: live, virtual, and constructive (LVC). Each of these categories of simulation has a specific purpose when used individually.

Live simulation training is normally what the layman visualizes when he thinks of Army training. Live simulation, defined by AR 350-1, is "real people operating real equipment" (Army, 2011). Initial entry level Soldiers (recruits) spend the bulk of their basic training conducting live simulation training, such as obstacle courses, firing ranges, and field training exercises (FTX). Live simulations are used to integrate recruits into the Army. The overall purpose of these live simulations is to develop the Soldier's warfighter skills.

To enhance the training value of FTXs and other training events, the Army created PEO-STRI, located in Orlando, Florida. PEO-STRI focuses on the procurement and fielding of TADDS (Training Aids, Devices, Simulators, and Simulations) in order to provide realistic training environments for Soldiers. Two of PEO-STRI's current projects to enhance live simulation training are the Instrumentable Multiple Integrated Laser Engagement System - Individual Weapon System, better known as IMILES-IWS and the Instrumentable Multiple Integrated Laser Engagement System Tactical Vehicle System known as IMILES-TVS.

The IMILES-IWS and IMILES-TVS provide real-time casualty effects for tactical engagement training in direct-fire, force-on-force training scenarios, and instrumented training scenarios (LTS, Live Training Systems). Both the IMILES-IWS and IMILES-TVS have integrated technology that enables the system to encode/decode weapon type, ammunition type, player identification, and weapon/ammunition lethality effects information creating realistic combat adjudication.

Figure 1: IMILES-IWS mounted on 25th ID Soldier's weapon and Kevlar; IMILES-TVS fitted on a HMMWV (LTS, Live Training Systems).

The second category of Army simulations is virtual simulations. AR 350-1 defines virtual simulations as "simulation involving real people operating simulated systems" (Army, 2011). Virtual simulations inject humans-in-the-loop in a central role by exercising motor control skills, communication skills, and decision skills. The most common examples of virtual simulations are the Army's flight simulators. PEO-STRI has initiated the fielding the Additional Black Hawk Flight Simulators (ABHFS) to meet the high demand of flight simulator use by aviators. The ABHFS provides Army aviators realistic environment training for basic, advanced, emergency, and instrument flight maneuvers (Product Manager for Air and Command Tactical Trainers-PM ACTT). The training benefit virtual simulators provide over live simulations is their ability to train highly dangerous, complex missions and maneuvers without the risk of loss of life or equipment. This benefit allows Army aviators to train and become proficient on tasks they normally would not be able to practice in a real aircraft due to the inherent dangers or financial expense associated with them.

Figure 2: Cockpit of a ABHFS (Product Manager Air and Command Tactical Trainers, PM ACTT)

The third category of Army simulations is constructive. AR 350-1 defines constructive simulations as “simulations that involve simulated people operating simulated systems” (Army, 2011). In constructive simulation training, real people make inputs to simulations, but are not involved in determining the outcomes. The Army uses constructive simulations to “drive” command post exercises (CPX). CPXs are used to train Army leaders and their staffs in the collective battle tasks, such as battle tracking and synchronizing assets across the area of operations. The benefit of constructive simulations is they enable Army commanders to train their staffs at a fraction of the cost of using live simulations. Constructive simulations also allow Army leaders and their staffs to train with minimal involvement of their Soldiers. This frees up Soldiers’ time to continue developing and honing individual warfighting skills. The Army sub-characterizes constructive simulations into two groups based on the size of environment they were developed to train. The first group is brigade and below training environments and the second group is brigade and above. Brigade and below simulations typically have a higher resolution and fidelity than the brigade and above simulations as they simulate a significantly smaller size force. OneSAF (One Semi-Automated Forces) is an example of an entity level constructive simulation used to support brigade and below training environments. OneSAF is labeled as an entity simulation as the objects in the simulation represent individual Soldiers, platforms, units, and behaviors enabling a high resolution and fidelity capability.

Brigade and above constructive simulations account for the time and space factors associated with large unit movements such as divisions and corps. The Warfighter's Simulation (WARSIM) is an example of a brigade and above constructive simulation. WARSIM is designed to increase the effectiveness of commander and staff training by providing realism and scope covering the full spectrum of military operations. "The WARSIM system uses a software computer-based simulation and associated hardware to support the planning, decision-making and operational execution of unit commanders and their staffs from battalion through theater level as well as the training events in educational institutions" (Project Manager Constructive Simulation, ConSim).

Figure 3: WARSIM (Project Manager Constructive Simulation, ConSim)

Although the Army has categorized its simulations into three distinct groups, the Army strives to integrate and develop these three groups into a single environment; the live, virtual, constructive integrated training environment (LVC-ITE) using a LVC Integrating Architecture (LVC-IA). According to the current Army training publication, AR 350-1 (Army Training and Leader Development), the Army strives to use all three categories of simulations to create a LVC environment that enhances training (Army, 2011). However, integrating and creating interoperable LVC environments has posed several challenges for the U.S. Army for over a decade for multiple reasons. A primary reason is that simulation technically has continued to evolve increasing the complexities of the models (Henninger, Cutts, Loper, Lutz, Saunders, & Swenson, 2008).

Two of the factors that made integrating LVC difficult were the rapid adoption and expansion of modeling and simulation (M&S) across Army activities that neglected to foster the required interoperability, integratability, and composability to efficiently support a LVC integrated architecture. This was partially due to M&S systems maturing faster than the management of them (Davis & Anderson, Improving the Composability of Department of Defense Models and Simulations, 2003). In a short time, M&S became a primary tool for Amy's research development, concept analysis, and training communities (Henninger, Cutts, Loper, Lutz, Saunders, & Swenson, 2008). In order to appreciate the rapid adoption and expansion of M&S, a brief review of Army M&S history is required.

History of Modern Army Simulation and its Architecture

The history of modern Army unit-level, team and command & control training M&S for armored platoons began with the development of Simulation Network, better known as SIMNET. SIMNET started as a Defense Advanced Research Projects Agency's (DARPA) research prototype to investigate the possibility of developing a real-time distributed simulator for combat simulation (Pimental & Blau, 1994). The purpose of the DARPA project was to create a network of tank simulators that could be used for collective training in simulated combat scenarios and mission rehearsals. The SIMNET design goal "was to make the crews and units, not the device, the center of simulation" enhancing the training value (Lantham, 2003).

The result of DARPA's SIMNET project was the Army's first real-time distributed vehicle simulation used extensively by the U.S. Army to train unit-level, combat operations. It allowed for the synchronization of the capabilities of aircraft and ground vehicles in a virtual battlefield. The training value of SIMNET, and ultimately M&S as a whole, was solidified with the United States' quick and decisive victory over Iraq during Operation Desert Storm in 1991. In one of the most decisive tank battles since World War II, four U.S. armored cavalry troops destroyed two Iraqi armored brigades, outnumbering the U.S. tanks eight to one in the Battle of 73 Easting (Houlahan, 1999). A U.S. troop commander during this battle, Captain HR McMaster testified before the Senate Armed Services Committee that SIMNET contributed to the training that prepared his unit for combat. He testified, "tactical engagement simulation offers a way of providing a surrogate for combat experience..It can help identify those with the aptitude for combat, teach them relevant skills, and build both their competence and their confidence" (Gorman & McMaster, 1992). The success of SIMNET propelled the U.S. Army's use of M&S in the areas of research development, concept analysis, and training. M&S enabled the U.S. Army to test equipment, safely train Soldiers and units, and analyze inherently dangerous missions, and explore non-standard applications prior to combat.

From an operations and training perspective, the surge in simulation technology and use was plagued by fragmentation and limited coordination between the U.S. Army branches due to divergent operational demands and the inability of technology to provide a “one shoe fits all” solution to the divergent needs of the operations and training community. This led to the consensus that limited interoperability was the highest level of integration possible at the time, which in turn led to "stove-pipe" developments across the Army's warfighting functions: movement and maneuver, command and control, sustainment, protection, intelligence, and fires

(Ceruti, 2003). The stove-piped systems were "able to send data to other applications within the same domain but not across boundaries" (Hobbs, 2003). The "stove-pipe systems [were] built with different suites of sensors, networks, protocols, hardware, and software" (Powell & Noseworthy, 2012). This challenge of linking stove-piped systems was identified in a 1990 report to Congress. The congressional report directed the creation of an Office of the Secretary of Defense (OSD) program office..."to establish interoperability standards and protocols..." (Senate Authorization Committee Report FY91, 1990). This congressional directive led to the creation of DMSO (Department of Modeling and Simulation Office) and AMSO (Army Modeling and Simulation Office) with the task of synchronizing the efforts of simulation development. DMSO, renamed as the Department of Defense (DoD) Modeling and Simulation Coordination Office (M&SCO), still has the mission of "fostering the interoperability, reuse, and affordability of crosscutting M&S" (M&SCO).

Military Simulation Architectures

In an attempt to answer the challenge of establishing interoperability standards and protocols, M&SCO and AMSO published and mandated several simulation architecture standards as simulation technology evolved over the past 12 years. According to the DoD M&S Glossary, architecture is defined as "the structure of components in a program or system, their interrelationships, principles, and guidelines governing their design and evolution over time." These simulation architectures included the Distributed Interactive Simulation (DIS) and High Level Architecture (HLA) (M&SCO). Two additional simulation architectures, Test and Training Enabling Architecture (TENA) and the Common Training Instrumentation Architecture (CTIA), were developed by other government agencies in an attempt to increase the performance and level of interoperability within simulation systems (Morse, Lightner, Little, Lutz, & Scrudder, 2006) (Powell, 2005). Although DIS predates the creation of DMSO and AMSO, the DOD and the U.S. Army were essential in coordinating this simulation architecture into a variety of training and research simulations.

Distributed Interactive Simulation

The Defense Science Board and the Army Science Board researched the application of using DIS architecture to enhance distributed training between 1988 and 1994. This effort resulted in DIS standards being developed over a series of DIS workshops at the Interactive Networked Simulation for Training symposium. The symposium was sponsored by the University of Central Florida's (UCF) Institute for Simulation and Training (IST) in support of the Army's SIMNET program (Davis P. K., 1995). DIS architecture and protocols made it possible to link "various combinations of live, virtual, and constructive models that [are] geographically separated;...collect relevant data...and use exercises and simulator operations to conduct well designed experiments to inform models and analysis" (Davis P. K., 1995). The DIS standards and protocols "enabled heterogeneous simulations to interact in a shared virtual environment" and remained the primary simulation architecture for Army Simulations until the introduction of the High Level Architecture (HLA) in 1996 (Hoxie, Irizarry, Lubetsky, & Wetzel, 1998).

High Level Architecture / Run-Time Infrastructure

DMSO merged the DIS protocol with the Aggregate Level Simulation Protocol (ALSP) in order to produce the HLA for distributed computer simulations (Morse, Lightner, Little, Lutz, & Scrudder, 2006). ALSP was a 1990 DARPA project to study the application of DIS principles used in SIMNET. ALSP added time management and object ownership capabilities to DIS supporting DMSO's goal to "increase interoperability and code reuse of defense modeling and simulation components" (Hoxie, Irizarry, Lubetsky, & Wetzel, 1998). The DMSO motivation of moving away from the protocol specific to the DIS architecture was that the HLA defines a broad set of rules governing how simulations interact with each other allowing a "contemporary approach of separating the data model and the functions of methods for exchanging information" (Morse, Lightner, Little, Lutz, & Scrudder, 2006). The HLA provided the common architecture for distributed modeling and simulations enabling federated simulations systems. Federated simulations, or federations, was the system of systems approach supporting interoperability among separately developed simulations (Davis P. K., 1995) (Morse, Lightner, Little, Lutz, & Scrudder, 2006).

While the HLA Standards dictate how federates exchange data, it is a FOM (Federation Object Model) that dictates what data is being exchanged in a particular federation. Federations are based on different needs of the M&S users. The most common FOM is the Real-time Platform-level Reference Federation Object Model (SISO). Other Federations may have different object models depending on such things as time management schemes that are not real-time or entity representations that are not platform level but rather aggregates, such as military units. The Aggregate Level Simulation Protocol (ALSP) supported such a federation (Weatherly, Wilson, Canova, Page, Zabek, & Fisher, 1996). Currently the Joint Land Component Constructive Training Capability (JLCCTC) effort is attempting to bring these two communities together as discussed in more detail below.

There are four fundamental concepts of the HLA federation that enable interoperability. The first is they are made up of a collection of simulations (federates). The second concept is the interactions between federates are by time stamped events. The third is standardizing the requirement to define common objects and events that are shared among multiple simulations. The fourth is they use middleware called run-time infrastructure (RTI) software to provide common basic services to support interoperability such as standardized interface and federation management support functions (Santoro & Fujimoto, 2008).

In addition to the fundamental concepts of the HLA federation, there are three core specifications that define HLA. These core specifications are described in table 1 below.

Table 1: HLA core specifications, derived from Morse's article (Morse, Lightner, Little, Lutz, and Scrudder, 2006)

Core Specification	**Description**
Institute of Electrical and Electronics Engineers (IEEE) standard 1516: HLA Framework and Rules	A set of 10 rules, five applying to federates and five applying to federations, that define the interaction and responsibilities of federates and federations
IEEE standard 1516.1: HLA Federate Interface Specification	Specifies the RTI services and interfaces implementation for correct operation of federations and the call back functions that federates must provide. It also includes language-specific application programming interfaces (APIs) for services and callbacks.
IEEE standard 1516.2: HLA Object Model Template (OMT)	A template that specifies the federates capabilities to exchange data (known as a simulation object model or SOM) and the data to be exchanged during federation execution called a federation object model (FOM). It also supports federation agreements such as transportation types, switches, and user-defined tags.

The Simulation Interoperability Standards Organization (SISO) maintains these three IEEE standards and is responsible for revising them as technology advances (Santoro & Fujimoto, 2008). As an example, two of these revisions in the IEEE standard 1516.2 series were the Web Services Definition Language (WSDL) API and the Extensible Markup Language (XML). The WSDL API revision was due to the evolving service-orientated architectures (SOAs) and to satisfy the requirement to make simulations available as Web services and to operate within a Web service environment. The XML schemas updated the OMT data interchange format by "including explicit support for data typing, greater extensibility, and support for namespaces" (Morse, Lightner, Little, Lutz, & Scrudder, 2006).

To ensure that new simulations created would be compliant with HLA, DoD directed that all new simulations after 1996 be HLA compliant (U.S. Department of Defense, Under Secretary of Defense for Acquistion and Technology, USD (A&T), 1996). Difficulties arose enforcing compliance and after several waivers for Army simulation systems as well as the lack of power of enforcement of the standard on operational units and other major stakeholders, HLA did not achieve its goal of a DoD wide standard. One may argue that HLA never had the potential to provide a DoD standard as the many FOMs that existed were inherently incompatible (U.S. Department of Defense, Under Secretary of Defense for Acquistion and Technology, USD (A&T), 1996). One may also argue that PEO-STRI could not update HLA at the pace needed to support the rapidly evolving needs of operational units (Henninger, Cutts, Loper, Lutz, Saunders, & Swenson, 2008). As discussed below, this also proved to be true. The lesson to be learned from HLA is that successful interoperability goes beyond technical requirements to such things as operational needs, command relationships, and continuous technology evolution.

Test and Training Enabling Architecture

Another simulation standard that has leveraged both the DIS and the HLA technology is TENA. TENA was developed as a Central Test and Evaluation Investment Program (CTEIP) project, currently led by Dr. J. Russell Noseworthy, and managed by the DoD's Test Resource Manage Center (TRMC). TENA has been used in testing and training exercises since 2002 to enable interoperability among ranges, facilities, and simulations (Noseworthy, 2010). The purpose behind the development of TENA was to support "live" training interoperability as the majority of software architectures originally developed to support distributed simulation systems were not " well suited to support the live component of LVC systems due to the fact that when real, live systems are mixed with virtual reality and/or constructive simulations, the demands of the live systems dominate the resulting LVC system" (Powell & Noseworthy, 2012). TENA's development approach combined both DIS and HLA/RTI technology to resolve the common protocols and data agreement aspects of interoperability. The TENA architecture is primarily used by the DoD testing and training community supporting large-scale, real-time, distributed simulation systems. The core principle of TENA is TENA middleware, which links together an unique combination of model-driven, code-generated software with improved programming abstractions and an API designed to detect programming errors at compile-time rather than run-time (Noseworthy, 2010) (Powell & Noseworthy, 2012). This is made possible by the TENA Middleware's ability to combine "the programming abstractions of distributed shared memory, anonymous publish-subscribe, and model-driven distributed object-oriented programming into a single intuitive middleware system (Powell & Noseworthy, 2012). TENA middleware is continuously being modified to support their M&S user base and as of February, 2012, the most current version is version 6.0.1 (Powell & Noseworthy, 2012).

Common Training Instrumentation Architecture and the Live Virtual Constructive - Integrating Architecture

Similar to specific requirements driving the development of TENA, CTIA was developed by PEO-STRI to provide an architecture for a product line approach to support live training across a wide range of products from the Combat Training Centers (CTC) to home station training systems. The product line approach "provides commonality across training instrumentation systems and interoperability across LVC and joint training systems" (Kemper & Lanman, 2012). The CTIA is the foundation architecture of the Live Training Transformation Family of Training Systems (LT2-FTS) strategy and will provide integration and interoperability with PEO-STRI's LVC-IA effort. The LVC-IA is a network-centric linkage that collects, retrieves and exchanges data among live instrumentation, virtual simulators, and constructive simulations as well as between Joint and Army Mission Command Systems. The LVC-IA recently went through a Government Acceptance Test (GAT) in July 2012 in Korea (PEO-STRI).

Early and Present M&S Challenges

In spite of efforts to create, maintain, and evolve interoperable simulation architectures, interoperability remains one of the greatest challenges in establishing an operationally valid LVC environment. The challenges facing the military M&S program in Table 2 below compares the 1996 challenges associated with the technical and managerial aspects with a similar study conducted in 2009 (Funaro, 2009). Both technical and managerial challenges are faced locally (at the micro level) as well as DoD-wide, DoD industry-wide, and communication industry-wide (at the macro level). Take particular note that even though interoperability was identified as a congressional issue in 1990, it has been listed as a challenge in 1996 and as a remaining challenge in 2009.

Table 2: 1996 and 2009 M&S Challenge Comparison (Funaro, 2009)

Type	**1996 Challenges**	**2009 Challenges**
Technical	Interoperability Data Description Physics based M&S Hardware and Software Limitations Variable Resolutions	Interoperability Data Discovery Security Representative, Composeable and Validated Models Fault Monitoring and Persistence Fidelity, Scale, and Resolution
Managerial	OSD and Army Guidance Ownership of Data and Models VV&A Funding Process Use of System Model	Governance, Standards Policies Data & Model Mediation VV&A Consistent Funding Efficient Use and Best Practices

The first goal listed in the Army Modeling and Simulation Strategy is to "advance interoperability and the use of common M&S capabilities" demonstrate that the U.S. Army continues to struggle with simulation interoperability (U. S. Army, 2012). Compounding the micro and macro technical and managerial challenges cited above is continuous evolution of technology and the related turbulence at the macro-level resulting in the generalized evolution of expectations and needs of users (Bower & Christensen, 1995). Life cycle, macro-level evolution of technology can easily be seen in such a simple example as the evolution of video recording from VHS to DVD to Blu-Ray with the concurrent turbulence associated with the rise and fall of competing standards. This requires that the Research Development and Engineering Centers supporting PEO-STRI and other DoD simulation, interoperability, and information program executives must at least keep pace with evolving computer and software technology. Further complicating the challenges is the hope of integrating live systems into training so that units may train as they will fight. This places additional requirements on weapon system program executives to be involved in resolving the interoperability challenge. Thus given the scale, scope, and depth of divergent and evolving systems implies the challenge of interoperability of those systems is computationally at least non-deterministic polynomial time (NP) hard. The difficulties of interoperability cause Army organizations to develop and implement non-standard simulations architecture multiple times in order to accomplish their mission. Perfect examples of this is the 25th Combat Aviation Brigade, 25th Infantry Division's (25th CAB) 2009 Operation Iraqi Freedom (OIF) and 2011 Operation Enduring Freedom (OEF) pre-deployment Culminating Training Exercises (CTE). Having served in the 25th CAB as the brigade's simulation and plans officer from January 2009 to July 2011, I have professional experience of their planning efforts of these two CTEs.

25th CAB Use Case

The 25th CAB is a Hawaii based aviation unit that had the task to plan, develop, and execute a CTE in order to prepare the unit for contingency operations in Iraq. In order to train their mission requirements in theater, the 25th CAB's CTE simulation planners needed to design an exercise incorporating six aviation battalion task forces, geographically separated by three distinct locations. The 25th CAB used the Tactical Engagement Simulation System (TESS) to instrument their live aircraft and the Initial Homestation Instrumentation Training System (I-HITS) to instrument Soldiers and ground equipment in order to integrate Live/Virtual operations during the exercise. The TESS and I-HITS live simulation instrumentations are similar to the previously discussed IMILES-IWS and IMILES TVS. Although not organic to Hawaii training center, the TESS equipment was used as it was only air certified training equipment that met the U.S. Army's Aviation standard for their fixed wing; see Appendix B, Airworthiness Release(AWR). This is the same equipment used exclusively at the three CTC (CMTC, NTC and JRTC) to support aviation units.

In addition to the use of TESS and I-HITS, two complete Aviation Combined Arms Tactical Trainer (AVCATT) virtual simulation suites were used to replicate both manned and unmanned aircraft, giving the 25th CAB twelve reconfigurable cockpits that could be used simultaneously. The 25th CAB used the Joint Conflict and Tactical Simulation (JCATS) constructive simulation as it was supported by their Maneuver Command Training Center as the backbone simulation to integrate the live and virtual simulations. JCATS is managed by the Joint Warfighting Center (JWFC) and its developer, Lawrence Livermore National Laboratory (LLNL) maintains the source codes for continued development and program enhancements (Shimamoto, 2000). Although One Semi automated Force (OneSAF) is the U.S Army's program of record for entity resolution constructive simulation, the 25 CAB used JCATS as OneSAF had not been fielded to the unit or to their supporting MCTC (PEO-STRI). Figure 4 below gives a brief overview of the CAB's 2009 CTE approach of using an LVC simulations to meet the training objectives of the CTE (25th CAB, 2009).

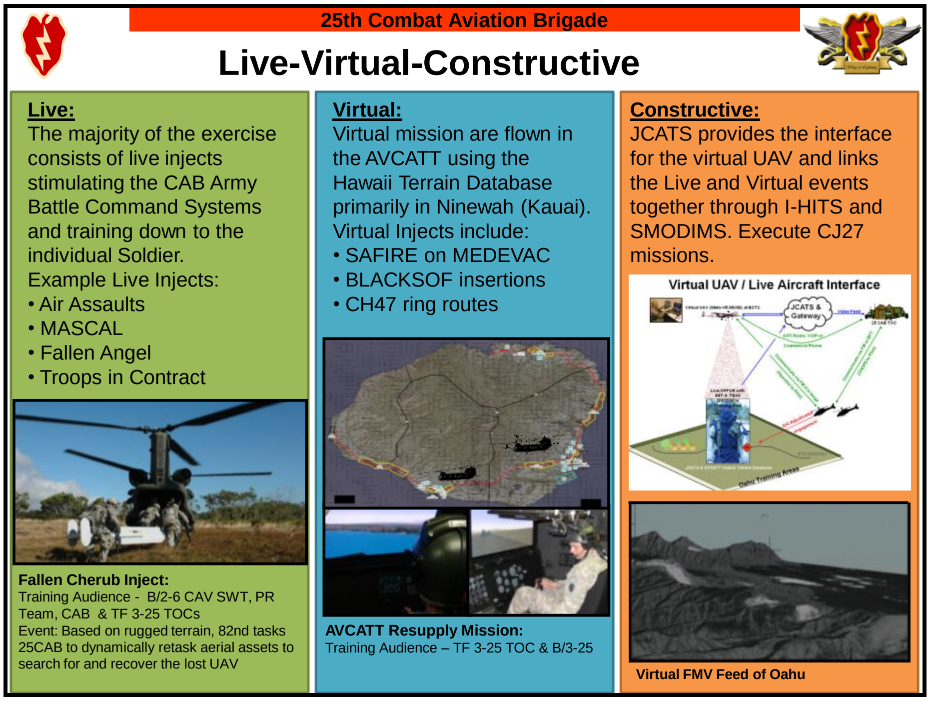


Figure 4: 25th CAB's LVC Concept of their 2009 CTE (MAJ Barry, 2010)

A few training objectives of the CTE included to execute training with the attack battalion from Germany using the AVCATT; train brigade and battalion task force staffs on planning and preparation of orders, execute full spectrum aviation operations with multi-functional task forces in a widely distributed operation environment; validate brigade standard operation procedures (SOPs); and rehearse battle drills for Aerial Reaction Force (ARF), Downed Aircraft Recovery Team (DART), Troops in Contact (TIC), Time Sensitive Targets (TST), Manned/ Unmanned Teaming (M/UM), and Personal Recovery operations. The detailed and specific training objectives of the CTE required an LVC integrating architecture to create network-centric linkages to collect, retrieve, and exchange data among the TESS and I-HITS live instrumentation, the AVCATT virtual simulation suites, and JCATS constructive simulations. Due to a lack of a pre-existing simulation integrating architecture as this was the first homestation Full Spectrum Aviation Exercise (FSAE) in Hawaii, the 25th CAB and their supporting Maneuver Command Training Center (MCTC) developed a non-standard solution.

Figure 5 below illustrates the complexities of the non-standard architecture technical design (25th CAB, 2009).

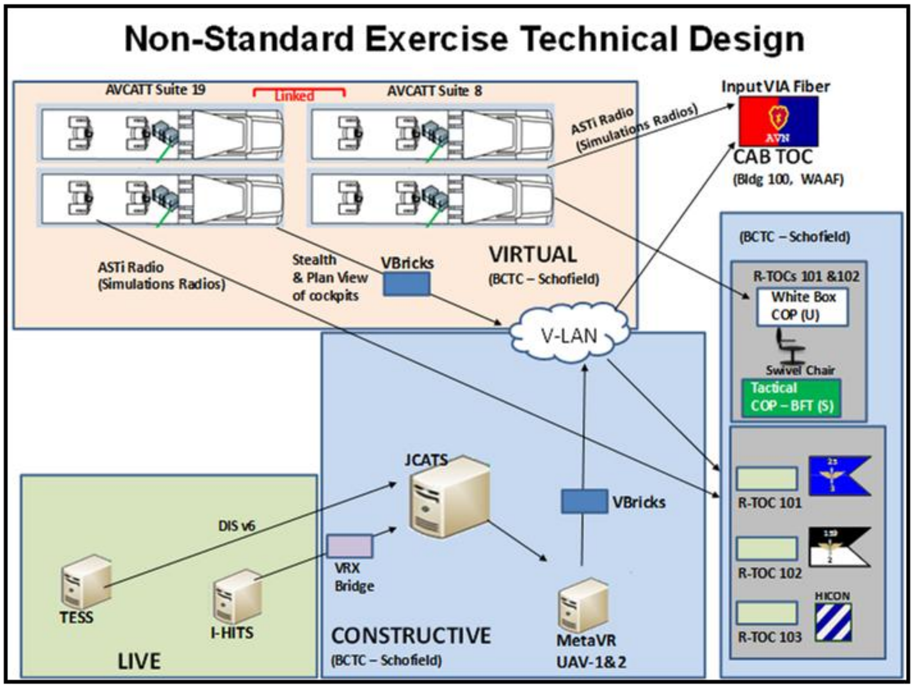


Figure 5: Diagram of CAB's CTE Non-Standard Exercise Technical Design (LTC Lang and MAJ Barry, 2009)

The next figure illustrates how the 25th CAB used the non-standard integrating architecture to accomplish Manned/Unmanned (M/UM) training with Unmanned Aerial Vehicles (UAV). The 25th CAB configured one of the AVCATT cockpits as a virtual UAV. This allowed the 25th CAB to send a video feed from the virtual UAV to the live training audience located in the Tactical Operating Center (TOC) via the JCATS and gateway bridge. The aircraft, ground equipment, Soldiers, and the opposing forces, fitted with either TESS or IHITS equipment, were integrated into the UAV feeds allowing the 25th CAB staff to train and develop tactics, techniques, and procedures on how to employ UAVs.

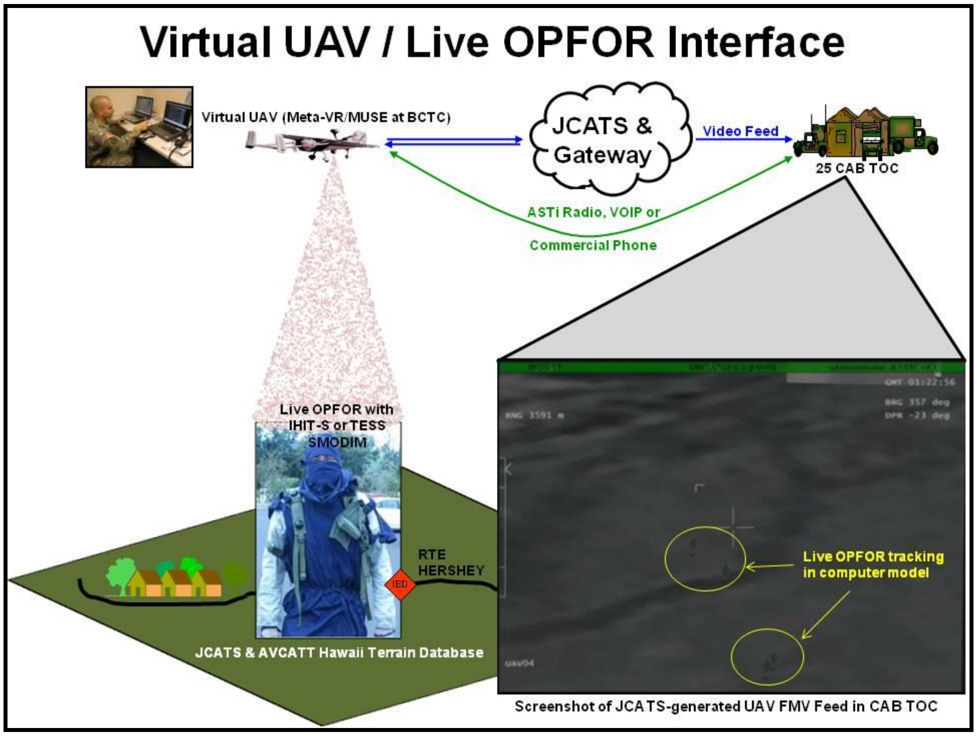


Figure 6: CTE Virtual UAV and Live simulation Interface (LTC Lang and MAJ Barry, 2009)

The 25th CAB and the MCTC spent over six months designing and testing the CTE simulation architecture. While it was almost impossible to track the additional hours the active duty Soldiers spent working to get the non-standard solution to function properly as they are not paid hourly, it is possible to track the money spent by the 25th CAB to the different organizations for the non-standard solution. Although the MCTC is already funded to support training exercises, the 25th CAB had to pay an extra $380,000 for overtime pay to the MCTC in order for them to develop and implement the non-standard simulation architecture in support of the CTE. In addition to overtime pay, the 25th CAB had to establish a $250,000 contract with private company, Inter-Costal Electronics (ICE), to connect the TESS instrumented aircraft to the JCATS constructive simulation and to provide live to virtual training support (25th CAB exercise budget). The ICE contact was required since neither the 25th CAB nor the MCTC had the resident expertise to integrate the live and virtual systems due to the lack of common protocols, specifications, and standardized LVC components among the government owned equipment.

Although the non-standard simulation architecture was expensive and required an extensive lead time to develop, it successfully supported the 25th CAB's 2009 CTE. Unfortunately, due to key personnel turnover and difficulty with interoperability, the time and money spent developing and executing the 2009 CTE non-standard LVC integrating architecture was repeated less than two years later in order support the 25th CAB's 2011 CTE in a similar exercise scenario. The short life cycle of personnel on station is an underlying variable that undermines continuity. Below is the concept design of the 25th CAB's 2011 CTE that prepared them for their OEF rotation.

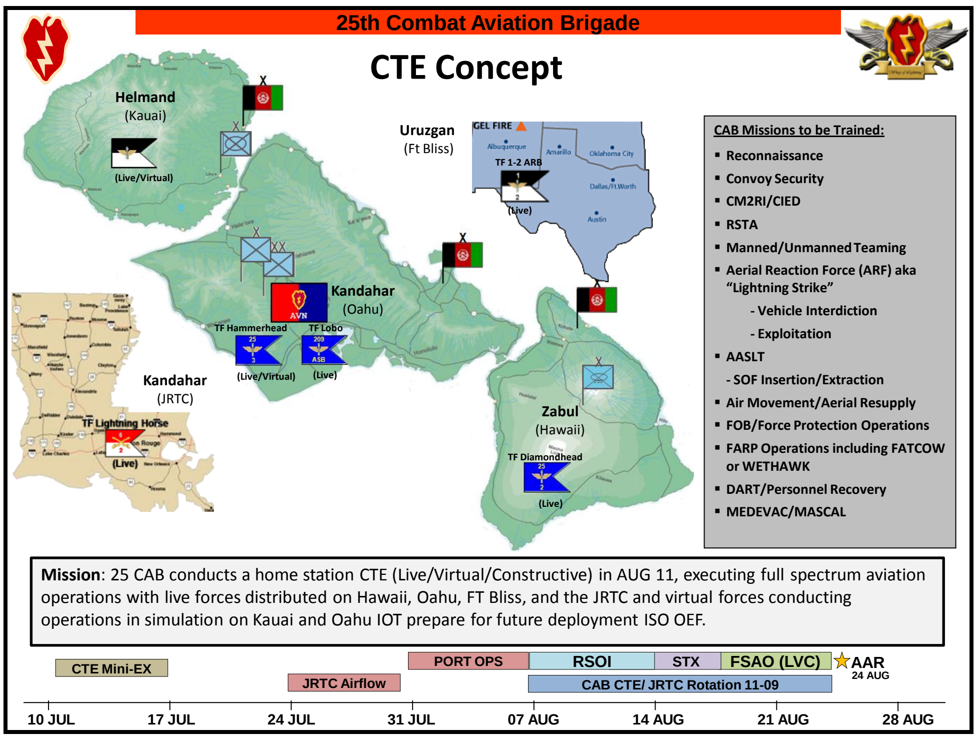


Figure 7: 25th CAB's 2011 CTE Concept (MAJ Barry, 2011)

Although the exercise scenario changed from Iraq to Afghanistan in the 2011 CTE, the requirement for a LVC architecture to integrate the live and virtual simulation components in order to replicate full spectrum aviation operations remained constant. Due to critical government and government contractor turnover, the lack of a standard LVC integrating architecture, and not using system engineering (SE) tools to document the architecture configuration; the 25th CAB had to spend approximately the same amount of time and money to develop another non-standard simulation architecture to support their 2011 CTE, see appendix A for the complete breakdown of 25th CAB 2011 CTE cost. The complexity of use, lack of required training, and lack of basic knowledge of SE tools as a whole prevented the 25th CAB from using them. The use of the system engineering process and tools, such the Federation Development and Execution Process (FEDEP) and the Distributed Simulation Engineering and Execution Process (DSEEP), might have mitigated the some of the negative impacts caused by the personnel turnovers (Henninger A. , Cutts, Loper, Lutz, Saunders, & Swenson, 2008). A few of these critical position turnovers included the MCTC director and simulation officer from the government side and the MCTC technical lead, AVCATT site lead, and AVCATT technical lead from the contractor side. The only means the 25th CAB was able to pay for these two exercises was through GWOT (Global War on Terror) dollars, which is supplemental funding for overseas contingency operations. As the wars in Iraq and Afghanistan are ending, the enormous amounts of money to establish the interoperable LVC architectures are coming to an end. The challenges of developing and executing a non-standard simulation architecture are not unique to the 25th CAB and are becoming common place within Army organizations that depend on simulations to accomplish their mission. Examples are the Mission Rehearsal Exercises (MRE) at Fort Lewis, Washington, with the 5th Stryker Brigade Combat Team MRE in 2008 and the 3rd Stryker Brigade Combat Team MRE in 2009. The Assistant Secretary of Defense for Networks and Information Chief Information Officer, Mr. John G. Grimes, acknowledged this common theme of creating non-standard training environments, "Patching stovepipes together is a temporary solution; however, this leads to a fragile environment, which will eventually crumble under the high demands and unpredictable needs of the users" (Department of Defense Chief Information Officer, 2006). Resource constraints will drive the U.S Army to develop and improve solutions to reuse their simulation architectures without having to redesign or rebuild them. Some of these attempts of increasing interoperability include creating tools to make interoperability easier and the use of Knowledge Management (KM) strategies to capture the documentation required to replicate the architectures are covered in Chapter 2.

CHAPTER 2: U.S. ARMY'S SOLUTIONS TO INTEROPERABILITY

Chapter 2 abstract:

The U.S. Army has struggled with simulation interoperability since the early 1990s. The U.S. Army has made strides in improving interoperability, but these improvements have been inadequate due to not keeping pace with the growing technical complexities of the simulations that are necessary to meet the needs of the users. To better understand the impact of the continued evolution of simulations, Maslow's Hierarchy of Needs has been mapped with the Levels of Conceptual Interoperability Model (LCIM). In examining this mapping, the highest level of needs, self-actualization, is paired with the highest level of the LCIM, conceptual interoperability. A key similarity to both the LCIM and the Hierarchy of Needs model is that each level increases with complexity and the proceeding lower level must first be achieved prior to reaching the next. Understanding the continuum of complexity of interoperability, as requirements or needs, helps to determine why the previous funding and technical efforts have been inadequate in mitigating the interoperability challenges within U.S. Army simulations. Some of these efforts include creating large simulation federations, overarching simulation integrating architectures, and databases. As the U.S. Army's simulation program continues to evolve while the military and contractor personnel turnover rate remains, for the most part constant, a method of capturing and passing on the tacit knowledge from one personnel staffing life cycle to the next must be developed in order to economically and quickly reproduce complex simulation events. A potential solution to this challenge is the Executable Architecture Systems Engineering (EASE) research project. The EASE project uses five unique components to provide an easy to use interface to allow M&S users an improved way to configure and execute M&S events while storing the technical design. However, there are two main drawbacks to

EASE; it is still in the prototype stage and has not been fully tested and evaluated as a simulation tool.

LCIM Mapped to the Hierarchy of Needs Model

For over twenty years, U.S. Army has addressed the requirement to link multiple simulations through the creation and management of several simulation architectures. Models and simulations are continually advancing in technology and growing in operational use in order to support the increasing needs of U.S. Army's simulation communities. This continued advancement in technology and increasing use makes integrating complex simulation systems more difficult. This evolution of need by the communities follows Abraham Maslow's psychological theoretical model of human motivation, Maslow's Hierarchy of Needs, developed in 1943. Maslow's model states there are five levels of ascending needs. In the ascending order they consist of physiological, safety, belonging, self-esteem, and self-actualization, and theoretically until the lower order needs are met, the higher order needs cannot be obtained (Maslow, 1943). See figure 8 below for a graphic depiction of Maslow's model.

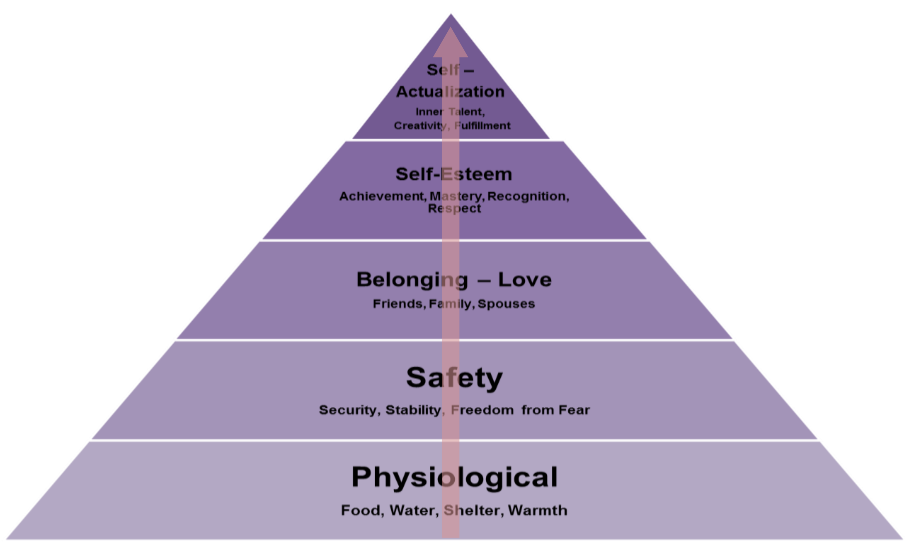


Figure 8: Derived from Maslow's Hierarchy of Needs (Maslow, 1943).

Theoretically as one moves to higher levels of the pyramid, the needs become more complex.

While Maslow's theoretical hierarchy and requirement that lower levels must be met before higher levels can be achieved has been a subject of debate and conflicting evidential research in the psychological literature, the notion of a hierarchy and some level of dependence of higher levels on some level of satisfaction of at lower levels at least from some psychological perspective stands (Neher, 1991)(Trigg, 2004). Similar to obtaining the lower order needs prior to higher order needs in Maslow's Hierarchy, the lower levels interoperability are typically first reached before the higher levels of interoperability are achieved. Tolk et. al. theoretically identified levels of Interoperability in his Levels of Conceptual Interoperability Model (LCIM). The LCIM is depicted in figure 9 below.

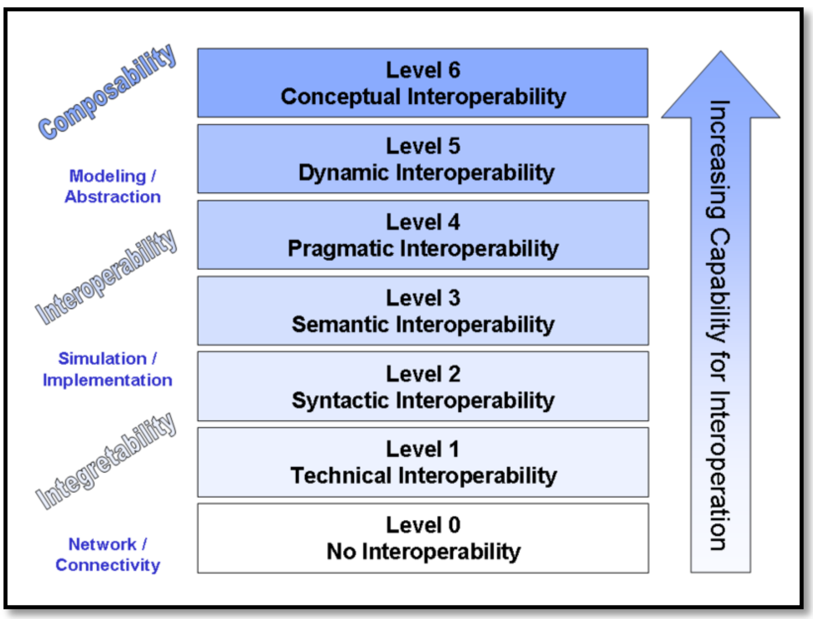


Figure 9: Levels of Conceptual Interoperability Model (Tolk et all, 2006)

Tolk et. al. describe the levels of interoperability as follows:

1. Level 0 - No Interoperability: These are stand-alone systems.
2. Level 1 - Technical Interoperability: A communication infrastructure is established enabling systems to exchange data. Basic connectivity is established and the communication protocols are explicitly defined.

3. Level 2 - Syntactic Interoperability: In this level a common data format is applied and the information exchange structure is explicitly defined.
4. Level 3 - Semantic Interoperability: In this level the meaning and content of the data is explicitly defined.
5. Level 4 - Pragmatic Interoperability: This level is reached when the information is exchanged and explicitly defined.
6. Level 5 - Dynamic Interoperability: To reach this level of interoperability, the simulations must understand the state changes that occur in the assumptions and constraints that each system is making over time and they are able to respond to those changes.
7. Level 6 - Conceptual Interoperability: This is the highest level of interoperability and is required for composability (Tolk, Diallo, Turnistsa, & Winters, 2006) (Turnista & Tolk, 2008).

Similar to Maslow's Hierarchy of Needs, in Tolk's theory, a simulation cannot reach the next level of interoperability until the subsequent level is obtained first. Tolk describes that interoperability is a continuum in which the levels of interoperability can be loosely grouped into three categories; integratable, interoperable, and composable. This is depicted in the LCIM (Tolk, Diallo, Turnistsa, & Winters, 2006) (Tolk A. , 2003). At the basic level, integration is achieved through network connectivity. With an increase of complexity, interoperation is achieved through the exchange of data elements based on common data interpretation demonstrating a system of systems perspective. Composability, the highest and most difficult level to reach, requires modeling abstraction. Simulation composability is analogous with self-actualization of Maslow's Hierarchy of Needs in that the lower order requirements must all be satisfied first. Composability and self-actualization both represent the highest attainable level in their respective paradigm, identifying the full potential of interoperability in the simulation system and the full potential of one's self. Mapping the LCIM against the Hierarchy of Needs shows how the Needs line-up with interoperability levels and illustrates the natural progression of simulation evolution.

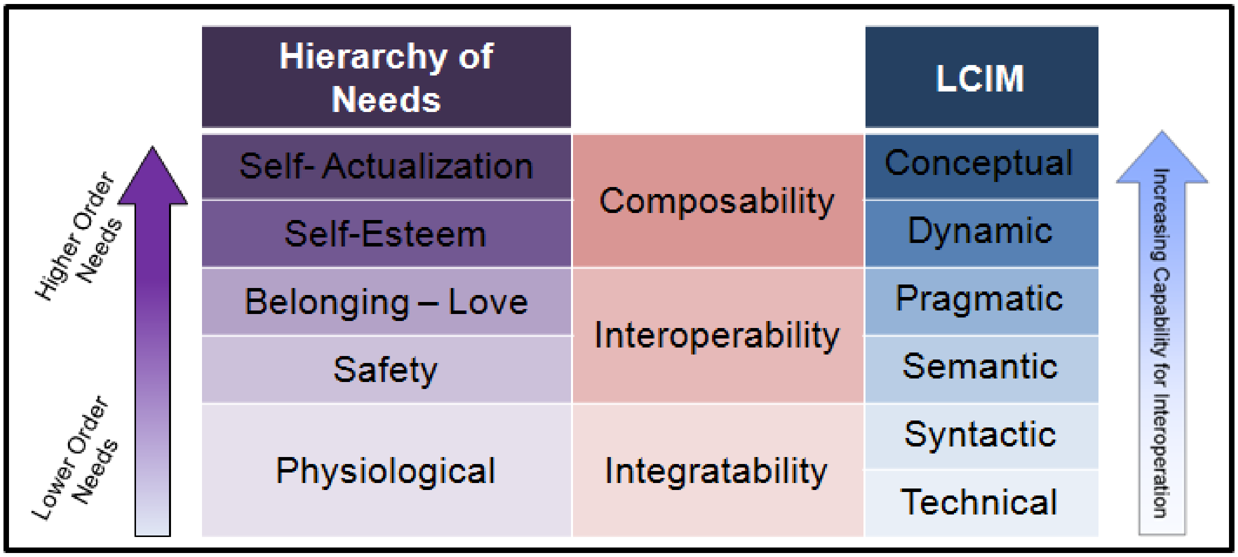


Figure 10: LCIM Mapped to Hierarchy of Needs, chart independently derived from Tolk and Maslow (Maslow, 1943) (Tolk et al, 2006)

A significant amount of effort has been spent creating simulation environments and conducting research in order to increase interoperability and ultimately composability within the simulation community. Composability in its most basic context is defined as "the capability to select and assemble components in various combinations to satisfy specific user requirements meaningfully " (Davis & Anderson, 2004). However, as previously discussed in Chapter 1, this high level of interoperability has posed a great challenge. It is naive to expect that composable simulation systems are simply a "plug and play" solution to the interoperability challenge. Based on their Congressional research, Davis and Anderson state that "...assembling model components in a new way may require weeks or even months of significant rethinking and adjustment, even when some or all of the components being used are quite apt." (Davis & Anderson, 2004). Although composability is the highest level of interoperability, it is not desirable in all U.S. Army Domains. For example, in the analysis community, interoperability is typically avoided with other simulations systems due to data miss-match issues and lack of or insufficient verification, validation, and accreditation (VV&A) of individual simulations or the newly created simulation environment. It could be argued that if "true interoperability" could be achieved in an economical fashion where models retain their VV&A when linked to other simulations, then the analysis community would be more receptive to the idea of interoperability. However, this is not the case and the excerpt below from Davis and Anderson's 2003 DoD report on composability reinforces that composability is not sought-after by the entire M&S community.

"...experts who understand composability issues and might be expected to favor composability per se, said candidly that they often find themselves arguing vociferously against composition efforts because the people proposing them do not understand how ill served end-users would be by connecting modules developed at different places and times and for different purposes, or how hard it is to understand the substantive consequences of connection such modules." (Davis & Anderson, Improving the Composability of Department of Defense Models and Simulations, 2003)

For the reason that the interoperability and composability is not required or wanted in all M&S communities, this thesis will focus on the efforts of increasing interoperability within the communities that will benefit from it such as the Training, Exercises, and Military Operations (TEMO) domain and portions of the research and experimentation simulation domains.

Joint Land Component Constructive Training Capability

The TEMO domain has invested significant amount of resources into the development of M&S software capability to increase interoperability. An example of a M&S software capability is PEO-STRI's Joint Land Component Constructive Training Capability (JLCCTC) effort. The

JLCCTC is composed of two separate federations, the JLCCTC Multi-Resolution Federation (MRF) and JLCCTC - Entity Resolution Federation (ERF). The purpose of JLCCTC is to "facilitate battle staff collective training by requiring staff reaction to incoming digital information while executing the commander's tactical plan" (PEO-STRI). The JLCCTC uses federate models that are connected by a combination of standard high-level architecture run-time infrastructure, distributed interactive simulation, custom interfaces, the master interface and point-to-point." (PEO-STRI). The purpose of JLCCTC fits the training requirements of the 25th CAB's CTE. Although, the current JLCCTC version 5.3 was fielded to Schofield Barracks in fiscal year 2011, the capability was not fielded to the Hawaii MCTC in time to support the CTE and therefore was not an option for the 25th CAB to use (United States Army). By design to meet the needs of the M&S training community, JLCCTC uses a combination of simulation architectures and a mixture of simulations requiring system configuration for each event (PEO-STRI). However, this requirement for system configuration could have potentially caused the 25th CAB to invest significant amount of time and money to tailor JLCCTC to fit their needs of executing a homestation FSAE. One of the significant reasons for this anticipated investment is that the multiple simulations systems and architectures that comprise JLCCTC were not originally designed to work together. It takes a significant amount of effort, resources, and collaboration to design highly interoperable and composable simulations systems. However, "...companies with bottom lines in mind will not invest in composability unless they can see the corresponding system being used and adapted enough over time to justify the costs." (Davis & Anderson, 2004).

Live Virtual Constructive - Integrating Architecture

Another investment the U.S Army is actively pursuing, to increase the level of interoperability of simulations systems, is the fielding of the LVC-IA to the MCTCs. The LVC-IA was briefly discussed in Chapter 1 and is the U.S. Army's program of record that will provide the protocols, standards, and interfaces required to create interoperability within the LVC training environment. The LVC-IA is scheduled to be fielded to 18 U.S. Army locations in the next six years at an estimated procurement and cost of 71.7 million dollars (U.S. Army, 2012). According to the Capability Production Document (CPD), the LVC-IA "capability is [a] combination of integrated architecture...The capability provides a modeling and simulation network-centric linkage that collects, retrieves and exchanges data among live instrumentation, virtual simulators and constructive simulations..." (U.S. Army, 2012). The LVC-IA is classified as a training enabler and not as a training system as it will use pre-existing software and hardware to interface with the home station training network infrastructure. The purpose of LVC-IA is to provide the required interoperability between systems to support the individual unit training requirements. Insuring backward compatibility, the LVC-IA will primarily support the HLA/RTI simulation architecture utilizing the JLCCTC as the baseline federate models. The LVC-IA is seen as the U.S. Army's solution of increasing the level of interoperability within the TEMO domain. "The LVC-IA must provide "Plug and Train" capability that allows the dynamic addition of key live and/or virtual TADSS [Training Aids, Devices, Simulators and Simulations] to an LVC event in-progress to provide the commander the flexibility to meet training objectives" (U.S. Army, 2012).

Although LVC-IA is the U.S. Army's current solution to decrease the burden of interoperability by creating a "Plug and Train" architecture, it is expected that significant amount of effort will still be required to tailor the LVC-IA and JLCCTC to meet the training objectives for each training exercise. As previously discussed, the JLCCTC is a combination of various software and architectures that requires specific manipulation and engineering to customize and support an LVC event. The LVC-IA is an additional layer of blended software and architecture placed on top of the JLCCTC solution that will require additional modification and engineering to support individual training requirements. Prior to the six year fielding effort, the U.S. Army has already identified the technical requirements of running and maintaining the LVC-IA as exceeding the capability and training of their uniformed simulation and network experts (U.S. Army, 2012). "LVC-IA is a technical system of hardware and software maintained by a support contractor" (U.S. Army, 2012). Only after LVC-IA has been fully fielded and in operation for several years can an honest assessment be made of benefits the LVC-IA program has brought to the U.S. Army's interoperability challenge.

Embedded Simulation Architecture Tools - Gateway Builder Utility

Another method the simulation community is using to solve the interoperability challenge is the creation of embedded tools into the simulation architecture to make the integration of different systems easier. As discussed in the first chapter, interoperability architecture brings obstacles of complexity as well as advantages as seen in DIS, HLA/RTI, CTIA and TENA. A way that TENA mitigates some of the complexity involved with using different architectures is use of their Gateway Builder Utility. "The Gateway Builder is an interoperability tool designed to significantly reduce the time, effort, and cost of integrating LVC applications that use different interoperability architectures into distributed training exercises and test events" (Powell & Noseworthy, 2012). However, the benefits of TENA's Gateway Builder has gone unmeasured, for the most part, in the U.S. Army's simulation program as they have not fully adopted the TENA architecture throughout their simulation domains from the DoD testing and training activities. The engineering approach of TENA is similar to HLA/RTI, except that the capabilities are easier to use but more restricted than HLA as it was designed for a specific M&S user group (Noseworthy, 2010). Based on the desire for more capability and flexibility, the U.S. Army has decided to use the HLA/RTI simulation architecture as their base-line architecture for integrating training simulation systems as seen in their current LVC-IA program of record (U.S. Army, 2012).

Knowledge Management

Another method the U.S. Army uses to help overcome the interoperability challenges, is knowledge management tools to help capture the best practices and lessons learned from integrating simulation systems. In their 2003 report to Congress, Davis and Anderson identified that one of the challenges of interoperability is the lack of documentation and knowledge sharing. The report states, "...major lessons-learned studies have been or are being conducted by the services and the joint staff on warfighting, but DoD has done nothing comparable to learn from its previous modeling and simulation composability efforts. ... the information will be lost as people retire and existing records disappear" (Davis & Anderson, Improving the Composability of Department of Defense Models and Simulations, 2003). The U.S. Army's approach to capture and reuse the information before it is lost is to rely on multiple databases. Both the U.S. Army and DoD maintain a Modeling and Simulation Resource Repository (MSRR) that "promotes interoperability, reuse, and commonality through information sharing and communication throughout the M&S Community" (AMSO). The Army MSRR contains information on data sources, documents, models and simulations, organizations and support utilities. The goal of the MSRR is to "facilitate internal, joint, and combined interoperability through the standardization and use of common data" (U.S. Army, 1999).

The two biggest challenges U.S Army has with depending on MSRRs to share knowledge is capturing of tacit knowledge and forcing the M&S communities to use them. This applies to both inputting the documentation and retrieving the documentation from the databases. There is a great disparity among the M&S domains that use and update the MSRR. In the transfer of knowledge, the U.S. Army is no different than other organizations trying to develop into a learning organization. The "creating, acquiring, sharing, and applying [tacit] knowledge" must be achieved first before an organization can successfully progress into a learning organization (Chinowsky, 2007). During the process of converting tacit knowledge into explicit knowledge such as procedures, rules, directives, and systems, better known as codification, substantial knowledge is lost (Grant, 1996). So far, technology has not been successful in overcoming this challenge of knowledge lost in KM programs. The most effective transfer of tacit knowledge generally requires extensive personal contact and trust from those who possess it (Fahey, Srivastava, & Smith, 2001). Relying on personal contact to transfer the tacit knowledge poses a dilemma in the U.S. Army's simulation community due to the high turnover rate seen in both the government and contractor workforce. The 25th CAB case study discussed in chapter 1 illustrates how multiple key personnel can change in less than two years time.

The U.S. Army continues to invest in various solutions to achieve improved interoperability. It has created and managed standard protocols, software, and simulation architecture. The U.S. Army also uses knowledge management technology to aid in the increasing of interoperability. These approaches alone have been inadequate as increasing interoperability remains one of the top challenges in the U.S. Army's M&S area. However, the U.S. Army recognizes the challenge of increasing interoperability among cross-service and cross-domain cannot be solved by funding, technological advancements, and M&S management. In acknowledging this gap in research and technology, the U.S. Army Research Laboratory (ARL) Simulation and Training Technology Center (STTC) has conducted research into advanced simulation methods and means in order to mitigate part of the interoperability challenge. The STTC has been working on an executable architecture based on systems engineering for distributed M&S.

Executable Architecture Systems Engineering

Given that no system will be perfect, the challenge created by interoperability incompatibility will be with units for the foreseeable future. The goal of the STTC's project, Executable Architecture Systems Engineering (EASE) is to allow the typical M&S user to find and execute a complete simulation environment that meets their requirements. The EASE project also helps close the gap between the shared knowledge captured in the various MSRRs with the tacit knowledge required to orchestrate the simulation distributed configurations. This is accomplished through a unique systems engineering infrastructure that captures important interoperability data from high level functional requirements that are used in implementation. The key personal on the EASE project are Christopher Metevier, U.S. Army program manager, Chris Gaughan, U.S. Army lead engineer and project manager, and Scott Gallant, U.S. Army contractor lead engineer and project manager. The EASE project is divided into five components; System Design Description (SDD), Systems Engineering (SE) Bridge, EASE Interview, Deploy Asset Management, and Workflow System (Gallant, Metevier, & Gaughan, Systems Engineering an Executable Archetecture for M&S, 2011). These components are illustrated in the figure 11 below.

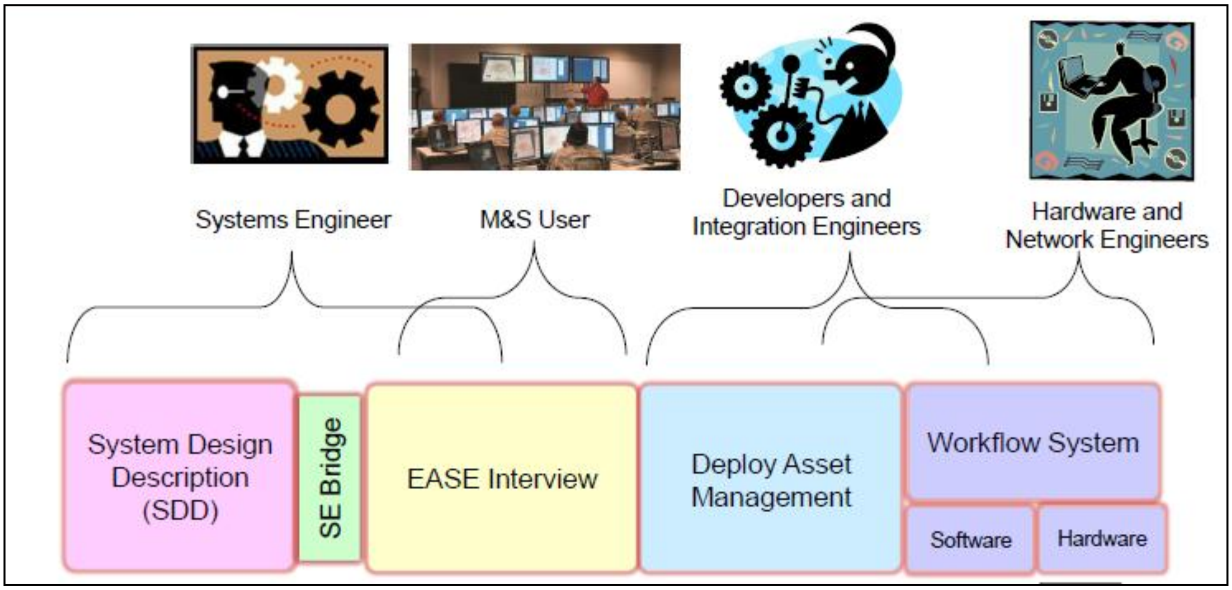


Figure 11: Executable Architecture System Engineering (EASE) Components (Gallant and Gaughan 2012).

Each of the EASE components has a specific role to lower the barrier of entry for M&S users by integrating the systems engineering information and have the requirements automatically executed to include providing After Action Review (AAR) information at the conclusion of the simulation run. The five EASE components are targeted to reduce the challenge of interoperability by capturing the simulation design in a set of composable building blocks and "establish true interoperability between components" (Gallant, Metevier, & Gaughan, Systems Engineering an Executable Archetecture for M&S, 2011). Two other essential goals of EASE in order to reduce the challenge of interoperability is to "manage configuration changes that affect functionality, scenario execution and technical execution consistently across [software] applications and link composable design to composable application configuration" (Gallant & Gaughan, EASE Prestentation to MDA, 2012).

System Decision Description

The first component of EASE, the SDD, is the key element that allows the applications and simulation/modeling components to interoperate. The purpose of the SDD is to provide the data decomposition requirements, system architecture guidelines, technical scenario files, and model selection in order to run a simulation event. The ability to reuse data decomposition requirements is a difficult engineering task and pivotal in reaching a higher level of interoperability that has stumped many M&S users. The difficulty of this task is expressed in Davis and Anderson's work, as they state, "many researchers involved with composability-related work emphasize that the data problem is one of the most important and most vexing issues" (Davis & Anderson, 2004). Figure 12 below describes how the SDD captures a system design at a functional level and links it to the technical design.

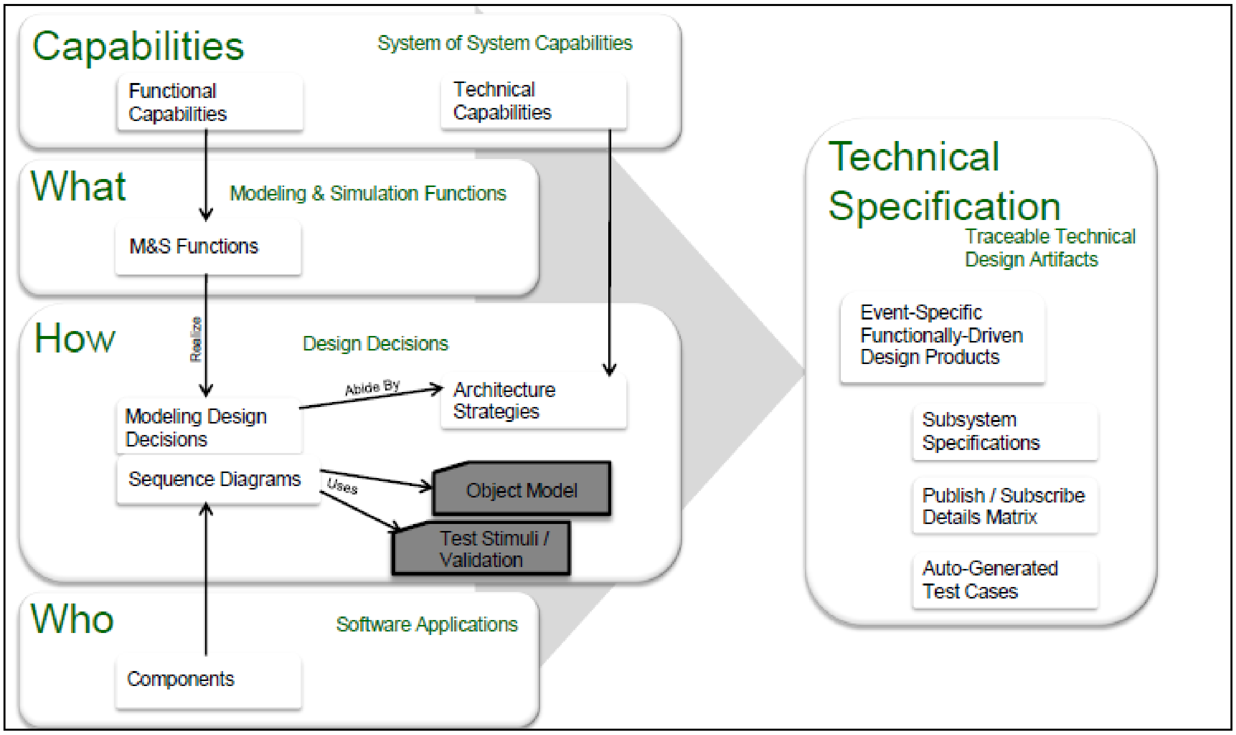


Figure 12: System Design Description (Gallant and Gaughan 2012)

As depicted in the SDD figure 12, components, functions, Modeling Design Decisions (MDDs), architectural strategies, and capabilities are used to define what the system does and how it accomplishes the required functionality. The increasing complexity of the simulation environment is directly related to the errors produced in the life cycle of designing, developing, integrating, testing, and reusing the distributed simulation environment. A key capability of the SDD is reducing these errors "by capturing as much data as possible...and automating as much of the deployment, configuration and execution details as possible, we can reduce the time and amount of errors introduced with late business or technical changes" (Beauchat, Gallant, & Metevier, 2012). The SDD's ability to capture the systems engineering data in a reusable way has enabled EASE to generate event-specific and design-specific simulation events, potentially increasing the level of interoperability among M&S tools. Other benefits of the SDD include supporting multiple views, providing configuration management, and eliminating the duplication of the same data since the information is only written once.

Systems Engineering Bridge

A drawback in the SDD is that it was designed for the simulation engineer and not necessarily for the basic M&S user. To help mitigate the systems engineering knowledge barrier, EASE uses the SE Bridge. The SE bridge is the EASE component that connects the SDD to the EASE interview allowing the M&S user to bypass using the engineer specific tool. "The bridge abstracts away the systems engineering tool specific database details and instead provides an Application Programmers Interface (API) in order to get the appropriate information on the simulation details" (Gallant S. , Understanding the EASE Components, 2012).

EASE Interview

In converse of the SDD, the third component of EASE, the EASE interview, was specifically designed for the M&S user. The EASE interview is an electronic interview interface that determines the specific implementation of models, scenarios and system designs based from the users' requirements. The EASE interview guides the M&S user through a systematic series of questions linking high-level warfare capability descriptions to low-level M&S functions executable by the SDD. The EASE interview provides the user interface that connects the lower levels of interoperability of the LCIM ranging from 1-3 to the high levels of interoperability up to level 6, conceptual interoperability. The EASE interview was developed for the M&S user that has basic understanding of the requirements for an M&S implementation and has the knowledge base to select the suitable set of military representations and scenarios required to meet the simulation event objectives (Gallant, Metevier, & Gaughan, Systems Engineering an Executable Archetecture for M&S, 2011).

Deploy Asset Management

The fourth component of EASE, the Deploy Asset Management, provides integration, configuration, and execution support of M&S event planning, instantiation, and analysis. The Deploy Asset Management uses cloud computing to distribute M&S through virtual machine management and Platform as a Service (PaaS). The Deploy Asset Management provides a single service that is used to "capture event objectives, stand-alone application configurations and cooperative applications configuration logics that are then used to deploy and execute in a dynamic virtual machine-based cloud" (Murphy, Diego, & Gallant, 2011). The benefit of providing a single service to launch the simulation is a reduction in time and money by getting rid of the requirement to manually configure and execute new sets of applications. It is expected that the Deploy Asset Management will provide added value to future M&S event planning as it will enable "repeatable and accurate executions, the ability to mature the platform over time, and by the direct linkage of the event purpose and the data collected within the cloud executions" (Murphy, Diego, & Gallant, 2011).

Workflow System

The final component of EASE, the Workflow System, allows for the flexibility of application life cycles by the addition of new, modified, or removal of software applications from EASE. The workflow system provides the process that controls how applications are requested, installed, configured, updated and removed. The workflow system is designed to manage the permissions, assignment, and resolution of tasks related to managing the backend execution details of EASE relieving the human burden of manually monitoring the workflow. This aspect of EASE is still immature and the Workflow System of EASE will allow the research to mature without limiting M&S engineers outside of the EASE project from benefiting from it (Gallant S. , Understanding the EASE Components, 2012).

The U.S. Army has invested many resources to include labor, time, and money developing technologies and approaches to mitigate the challenge of interoperability. The EASE research project has potential to lower the barrier of entry for M&S users to conduct repeatable distributed simulations events. The largest draw back in evaluating EASE as a solution to raising the level of interoperability within U.S. Army simulations is it has not be tested within any M&S community. Chapter 3 will discuss an evaluation plan of EASE to be used within the experimentation and research community.

CHAPTER 3: RESEARCH EXPERIMENTATION METHODOLOGY

Chapter 3 Abstract:

This chapter presents the methodology that will be used to execute the research. It summarizes the purpose of the research and describes the procedures for selecting the sample population of M&S users. The chapter explains the research questions, hypotheses, and the statistical techniques that will be used to analyze the answers to each research question. It then outlines the three phases that will be used in the research design and lists the assumptions that will be used in the research. It concludes with a discussion on the data collection methods and tools used to support the research.

Research Purpose

At a basic level, the purpose of this research is to test, evaluate, and provide an overall assessment of the EASE prototype as a potential M&S tool for the U.S. Army to help mitigate the challenges of interoperability. The general purpose of this research is to determine the extent such a tool can reduce the micro (local) as well as macro (industry wide) interoperability challenges discussed in Chapters 1 and 2. The expectation is that this tool will not only help reduce the local cost of achieving interoperability but will provide limited solutions in the way of addressing the macro challenges. In particular, expected benefits of this research in terms of macro challenges will be: (1) reuse potential of EASE within a Mission Training Complex (MTC); (2) reuse potential of EASE between MTC's; and (3) identification and better definition of macro interoperability challenges not addressed by EASE.

In this light, the research will consist of two parts. The first part will be an experiment involving EASE, which will gather data on the micro advantages of EASE. The second part will be solicitation of insights to the degree in which EASE addresses micro (both technical and managerial) and macro (technical, managerial, and life cycle) challenges highlighted in the previous chapters. While discussed in more detail below, the scope of the life cycle issues to be investigated in this research includes the short personnel and contractor support life cycles. It will also investigate to what degree EASE may ameliorate the costly and time consuming re-learning associated with the short personnel and contractor cycle cited in the preceding cases mentioned in Chapters 1 and 2.

Experiment Overview

The experiment will be constructed with the goal determining if the EASE prototype possesses the technology to provide an interface for designing and executing simulations as well as monitoring and collecting data for post simulation analysis. The experiment will also test the EASE prototype's capability of producing traceable execution runs based on functional and technical requirements of a simulation event. In addition, the experiment will evaluate the capability of EASE to launch simulations using virtual machines (VM) on a cloud-based set of computing resources. In order to determine the benefits of EASE, the M&S user community will test each component of EASE and provide feedback on the tests, overall anticipated applicability of the prototype, and recommendations. The end result of the EASE prototype research experiment will yield two essential pieces of information for the U.S. Army M&S community. The first piece is determining if the EASE prototype functions work as a solution to help mitigate the interoperability challenge. The second piece is the determination by the M&S user community of additional EASE functionality and improvements that will further benefit the U.S. Army simulation field.

Ideally, the research experiment would consist of several actual M&S events being run with and without using the EASE prototype allowing for a direct comparison. This would result in a more comprehensive analysis of the EASE prototype than using a single data scenario set.

However, the ideal research methodology would require exponentially more time and resources beyond the researcher's control. In addition, the EASE prototype has not reached a level of technical maturity to fully support an actual M&S event without the EASE project support staff. Despite these limitations, the present research experiment will be able to contribute to the research literature by providing a thorough evaluation of the EASE prototype as a potential U.S. Army M&S tool.

Study Population and Sample Population

The U.S. Army M&S community is currently divided into three domains based on how the simulations and models are used; Training, Exercise, and Military Operations (TEMO), Research, Development, and Acquisition (RDA), and Advanced Concepts and Requirements (ACR). The U.S. Army is in the process of transitioning away from these three domains and moving towards seven M&S communities: Acquisition, Analysis, Experimentation, Intelligence, Operations/Plans, Testing, and Training (U.S. Army, 2012). However, the draft AR 5-11, Management of Army Modeling and Simulation, is currently being staffed and has not been released for implementation, the three original M&S domains will be used in this research. The scope of the EASE research will focus primarily on the TEMO domain with supplemental participation from the ACR and RDA M&S communities. Fifteen M&S users will be selected from the results of a stakeholder analysis from 24 U.S. Army and 7 DoD organizations, listed in the table below, to participate in the EASE hands-on evaluation and research experiment.

Table 3: U.S. Army and DoD organizations used to sample M&S Users

Organization Name	**Short Name**	**Location**	**Domain**
Mission Training Complex - Fort Hood	MTC-Hood	FT Hood, TX	TEMO
Mission Training Complex - Fort Bliss	MTC-Bliss	FT Bliss, TX	TEMO
Mission Training Complex - Fort Campbell	MTC-Campbell	FT Campbell, KY	TEMO
Mission Training Complex - Fort Drum	MTC-Drum	FT Drum, NY	TEMO
Mission Training Complex - Camp Casey	MTC - Casey	Camp Casey, Korea	TEMO
Mission Training Complex - Fort Stewart	MTC-Stewart	FT Stewart, GA	TEMO

Organization Name	Short Name	Location	Domain
Mission Training Complex - Fort Riley	MTC-Riley	FT Riley, KS	TEMO
Mission Training Complex - Fort Carson	MTC- Carson	FT Carson, CO	TEMO
Mission Training Complex - Hawaii	MTC-Hawaii	Schofield, HI	TEMO
Mission Training Complex - Joint Base Lewis-McChord	MTC-JBLM	FT Lewis, WA	TEMO
Mission Training Complex - Fort Bragg	MTC-Bragg	FT Bragg, NC	TEMO
Mission Training Complex - Fort Knox	MTC-Knox	FT Knox, KY	TEMO
Mission Training Complex - Fort Benning	MTC - Benning	FT Benning, GA	TEMO
U.S. Army PEO Enterprise Information Systems	PEO-EIS	Orlando, FL	TEMO/RDA
U.S. Army PEO Simulation to Mission Command Interoperability	SIMCI	Orlando, FL	TEMO/ RDA/ACR
U.S. Army Program Executive Officer for Simulation, Training, & Instrumentation-Engineering Directorate	PEO-STRI Engineering	Orlando, FL	TEMO/RDA
U.S. Army Center for Army Analysis	CAA	FT Belvoir, VA	RDA/ACR
Assistant Secretary of the Army for Acquisition, Logistics and Technology	ASA(ALT)	Washington D.C.	RDA
Modeling & Simulation Coordination Office	M&SCO	Alexandria, VA	ALL
U.S. Army Modeling & Simulation Officer	AMSO	FT Belvoir, VA	ALL
Joint Mission Environment Test Capability / Test Resource Management Center	JMETC/TRMC	Washington D.C.	RDA
U.S. Army Materiel Systems Analysis Activity	AMSAA	Aberdeen Proving Ground, MD	RDA
U.S. Army Research Development and Engineering Command Modeling & Simulation Senior Working Group	RDECOM M&S SWG	Aberdeen Proving Ground, MD	RDA
U.S. Army Research Laboratory	ARL	Aberdeen Proving Ground, MD	RDA
U.S. Army Test and Evaluation Command Operational Test Command	ATEC OTC	FT Hood, TX	RDA
Assistant Secretary of Defense Research & Engineering Enterprise	ASD(R&E)	Washington D.C.	RDA
Defense Threat Reduction Agency	DTRA	FT Belvoir, VA	RDA
Joint Training Integration and Evaluation Center	JTIEC	Orlando, FL	TEMO
U.S. Army Capabilities Integration Center	ARCIC	FT Eustis, VA	ACR
U.S. Army Maneuver Support Center of Excellence	MSCoE	FT Benning, GA	ACR
U.S. Army TRADOC Analysis Center - Fort Leavenworth	TRAC-FLVN	FT Leavenworth, KS	ACR

The stakeholder analysis will consist of both a telephonic interview and an online EASE survey developed and maintained by the United States Military Academy (USMA). The survey and can be accessed at the following url: http://www.dean.usma.edu/se/SelectSurveyASP/TakeSurvey.asp?SurveyID=3317m46I8m25G . A copy of the survey questions are located in Appendix C. The purpose of the online questionnaire is to provide a stakeholder and value analysis of the most essential functions and attributes for EASE as opposed to being designed for statistical purposes. The survey will also serve as a mechanism for identifying possible participants for the EASE experiment. Therefore, the majority of the questions are open-ended in order to solicit unrestricted responses from the M&S community.

Eighteen of the 31 U.S. Army and DoD organizations were chosen based on their previous exposure to the EASE prototype through past demonstrations and meetings. The purpose of selecting organizations with prior knowledge of EASE is to increase the chances of organizations accepting invitations to participate in the three day testing and evaluation of the EASE experiment. The remaining 13 U.S. Army organizations used in the sample are Mission Training Centers, which mirror the type of simulation facility that supported the 25 CAB's CTE exercise discussed in Chapters 1 and 2. Based on their responses to the online survey, the M&S users were categorized as either a systems engineer, developer, management, scenario designer, or federation manager. In an attempt to get a mixture of the different types of M&S users to participate in the experiment, a random stratified method will be used to identify potential participants to receive invitations to the hands-on portion of the research experiment.

Research Questions, Hypotheses, and Analysis Design

The research focuses on three specific areas identified in chapter 2: managerial, technical, and personnel life cycle challenges. These three focus areas generate five research questions (RQ) that address EASE's limitations as a solution to the U.S. Army's simulation interoperability challenge. Analysis of the research questions will be based on frequency, descriptive and inferential statistics. The Wilcoxon signed rank-test will be performed using the IBM SPSS statistics software. The post Research Execution Phase (REP) questionnaire, located in Appendix D, was designed with closed and open form questions focusing on technical performance of EASE and the perceptions of the potential benefits of EASE. The perception response collection will be based on the Technology Acceptance Model developed by Davis (1985) and validated by Davis, Bagozzi, and Warshaw in 1989. The response levels for questions will be collected using the seven-level Likert scale shown below at Table 4.

Table 4: Technology Acceptance Model Response Scale

1	2	3	4	5	6	7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither Likely nor Unlikely	Slightly Likely	Quite Likely	Extremely Likely

Cronbach's Alpha will be used to conduct analysis of the internal reliability of perceptional responses for the Technology Acceptance Model. The post REP survey will be refined from feedback through pilot testing. The introductory section of the post REP survey, questions 1-7, and questions 15-17 gauges the participants' overall attitude on EASE.

RQ1. At what level does EASE mitigate the local (micro) technical interoperability challenges by enabling the set-up, execution, and documentation of M&S events? If deemed inadequate, what micro technical challenges must EASE solve in order to benefit the M&S community?

H_{01} = Expert stakeholders believe the EASE prototype does not have potential as a U.S. Army technical solution to help mitigate the M&S interoperability challenge.

H_{a1} = Expert stakeholders believe the EASE prototype does have potential as a U.S. Army technical solution to help mitigate the M&S interoperability challenge.

Post REP survey questions 8-12 and 24 will be used to address this research question. The Wilcoxon-signed rank test will be used to determine the statistical significance of inferences for groups and dimension combinations.

RQ2. At what level does EASE mitigate the local (micro) managerial interoperability challenges by enabling the set-up, execution, and documentation of M&S events? If deemed inadequate, what local managerial challenges must EASE solve in order to benefit the M&S community?

H_{02} = Expert stakeholders believe the EASE prototype does not have potential as a U.S. Army managerial solution to help mitigate the M&S interoperability challenge.

H_{a2} = Expert stakeholders believe the EASE prototype does have potential as a U.S. Army managerial solution to help mitigate the M&S interoperability challenge.

Post REP survey questions 13, 14, 18, and 25 will be used to address this research question. The Wilcoxon-signed rank test will be used to determine the statistical significance of inferences for groups and dimension combinations.

RQ3. At what level does EASE mitigate the knowledge management (KM) challenge of interoperability solutions caused by the short life cycle of personnel and contract support personnel? If deemed inadequate, what specific KM challenges does EASE must address in order to benefit the M&S community?

Research question three focuses on the life cycle challenges that are inherent to the M&S industry. While there are many different types of life cycles that surround M&S community such as product line, technology, funding, organization life cycles; the short life cycle of organizational and contract support personnel will be the only challenge addressed in this research.

H_{03} = Expert stakeholders believe the EASE prototype does not have potential as a U.S. Army knowledge management solution to help mitigate the M&S interoperability challenge.

H_{a3} = Expert stakeholders believe the EASE prototype does have potential as a U.S. Army knowledge management solution to help mitigate the M&S interoperability challenge.

Post REP survey questions 19-21 and 23 will be used to address this research question. The Wilcoxon-signed rank test will be used to determine the statistical significance of inferences for groups and dimension combinations.

RQ4. At what level does EASE mitigate the DoD wide (macro) technical interoperability challenges by enabling the set-up, execution, and documentation of M&S events? If deemed inadequate, what macro technical challenges must EASE solve in order to benefit the M&S community?

This research question addresses EASE's ability to serve the M&S community as a technical solution to the interoperability challenges. In order to adequately answer RQ4, multiple simulations events run over a course of months to years using EASE is required. This requirement exceeds the scope of this research and RQ4 will not be addressed.

RQ5. At what level does EASE mitigate the DoD wide (macro) managerial interoperability challenges by enabling the set-up, execution and documentation of M&S events? If deemed inadequate, what macro managerial challenges must EASE solve in order to benefit the M&S community?

Research question five addresses EASE's ability to solve interoperability issues caused by managerial challenges. Similar to RQ4, in order to adequately answer RQ5, multiple simulations events using EASE is required to generate the necessary amount of data to complete this analysis and therefore exceeds the scope of the current research and will not be addressed.

Assumptions

The following are the assumptions of the research study:

1. The 24 identified U.S. Army and 7 DoD organizations will provide a realistic sampling of the M&S user community.

2. The U.S. Army and DoD organizations selected to participate in the hands-on portion of the research experiment will accept the invitation to send their M&S users to the EASE prototype test site.

3. The pre-created scenario data given to the ACR M&S participants to test the EASE prototype represents actual requirements for simulation events.

4. One day of hands-on training will provide the M&S participants sufficient time to learn how to use the EASE prototype in order to execute the EASE testing and evaluation.

Research Design

There are three distinct phases of the EASE research; the stakeholder analysis, experimentation site preparation, and experiment execution. The stakeholder analysis will serve as a filtering mechanism to identify potential EASE users within the M&S community. The experimentation site preparation will determine the space, power, and execution requirements to run the experiment. The experiment execution phase will provide the required data for analysis in order to construct a comprehensive assessment of the EASE prototype.

Stakeholder Analysis Phase

The stakeholder analysis phase of the research is defined by creating, testing, and administering an online survey to the pre-identified M&S TEMO, RDA, and ACR community. The survey was created using a collaborative approach headed by an Operations Research Systems Analyst (ORSA) from the United States Military Academy (USMA) and assisted by the EASE project team and the author of this thesis. Once the online survey is created, it will be tested and modified multiple times before administering it to sample population. The average time to take the pilot surveys during the preliminary tests has been approximately 20 minutes. The 20 minutes includes a five minute introductory video that gives generic overview of EASE and highlights the major capabilities of the tool. The online survey will be administered using a web-based application maintained by USMA. The USMA ORSA analyst conducted a telephonic interview with each of the military organizations prior to releasing the survey to reduce the negative response rate and to increase the level of effort of the participants. The survey period will be opened for fourteen days, 14-28 September 2012, to accommodate the schedules of the participants. The results of the survey will be used to prioritize invitations for potential participants for the execution phase of the research. Twelve M&S users will be identified and invited as participants for the research execution phase. The names of the participants will be coded and remain anonymous in the attempts to foster honest responses and reduce biases.

Site Preparation Phase

The site preparation phase of the research experiment will consist of identifying the location of the research experiment; determine what hardware needs to be purchased, creating the data scenario, refining the after experiment questionnaire; and planning and setting up for the execution phase. An anticipated eight days will be used to create the data scenario and will be located in Appendix K. After the creation of the data scenario, 21 days will be spent testing and verifying the scenario on four separate machines using five different M&S users.

Also during this phase, two pilot runs of the post hands-on survey will be conducted in order to ensure clarity of each question. These test runs of the questionnaire will take place on 7 and 19 October at the experiment site located in Orlando on Research Parkway. It is expected that additional questions will be added to the post hands-on survey as a result of the pilot runs.

The below figure will contain a schematic drawing of the experiment test site.

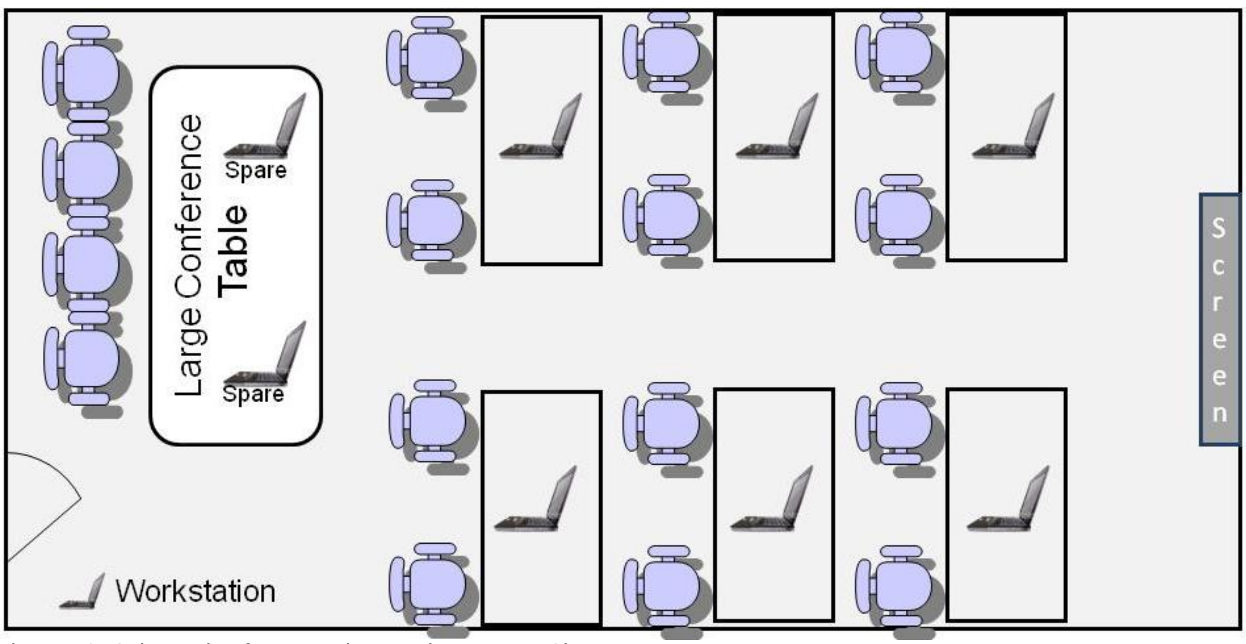


Figure 13: Schematic of Research Experiment Test Site.

In accordance with the experiment test site schematic, primary and spare workstations will be identified. The location of the computer processing units (CPUs) for the EASE servers will also identified. In addition to designing the experiment site layout, key life-support facilities will also be annotated such as hotels, restaurants, and gas stations so the information may be distributed to the experiment participants.

Research Execution Phase

The Research Execution Phase (REP) will consist of three days and take place from 24-26 October 2012 in Orlando, Florida. Fifteen invitations will be sent to the potential M&S EASE participants. The participants will be compensated for their participation by providing travel, lodging, and per diem costs for the duration of the experiment. The first day will consist of travel, site orientation, and an EASE overview. On day two of the REP, the participants will receive hands-on instruction on the operation of the EASE prototype. The hands-on instruction will culminate with recorded experiment runs of the EASE prototype using the data scenario as inputs. The participants' involvement in the research will conclude with a post hands-on survey, located in Appendix D. Day three of the REP will consist of discussions of EASE, after reaction review of the experiment, and return travel of the participants.

Data Collection Procedure

USMA will maintain the web based survey used to collect the stakeholder analysis data. The online survey will consist of six web pages and an EASE introductory video. The stakeholder analysis will assist in distinguishing between the targeted participants that possess the basic understanding of the requirements for M&S implementation from the M&S users that primarily interface with the simulation training audiences. During the REP, an evaluation matrix will be used by the participants as they execute the EASE prototype evaluation. This matrix will be used to collect data from the participants to determine the functional capabilities of the EASE prototype. An example of the EASE participant evaluation matrix is located in Appendix K. In addition to the evaluation matrix, each participant will fill out a post REP survey questionnaire at the conclusion of the hands-on evaluation, located in Appendix D.

CHAPTER 4: DATA COLLECTION AND ANALYSIS

Chapter 4 Abstract

This chapter presents data and analysis on the quality of the participants selected and on the research questions. The chapter also discusses participant demographics, data collection, and reliability of the post hands-on survey questions. The majority of the chapter focuses the analysis to the research questions (RQ1, RQ2, and RQ3) from the perspective of hypotheses testing. The chapter explains how the IBM SPSS software was used to create indexes associated with both the quality of participants and research questions and then how these indexes were used to perform the Wilcoxon Signed Ranked test. The Wilcoxon Signed Ranked test provided the statistical analysis that formed the basis of the research; to determine if expert stakeholders believe that the EASE project has the potential to help mitigate the interoperability challenges in the U.S. Army's M&S domains.

Participant Demographics

The target sample population for this research was the entire population of the participants for the EASE workshop held on October 24-26, 2012 (N=11). The participants traveled to Orlando from ten different organizations listed in Appendix N. There were four participants from each the TEMO and ACR domains and three participants from the RDA domain. Out of the eleven participants, there were six managers, four system engineers (SE), and one developer. Four of the six managers where either a SE or developer prior to working in their current capacity. The years of M&S experience of the participants ranged from three to twenty-one years with an average of ten years of M&S experience. In order to protect the names of the participants, the specific demographic data such as gender and age were withheld, along with the demographic data of the participants being linked to their organization due to the small niche population that comprises the U.S. Army M&S profession.

Data Collection

On the first day of the experiment each participant was given two and one-half hours of an EASE overview and instruction in accordance with the EASE workshop schedule located in Appendix O. On the second day of the experiment, October 25, 2012, each participant completed an EASE practical exercise that consisted of working through a four hour EASE scenario located in Appendix K. The hands-on scenario walked each participant through the five components of EASE. This included executing the following eight specific tasks of setting up and running a simulation:

1) Update the simulation system design with newly represented warfare capabilities using the SDD and SE Bridge.
2) Update and verify a test case in EASE so future software deliveries have correct functionality.
3) Update appropriate surrogates so developers can test their own software against a model that needs updating.
4) Export the test case and surrogate directly from the data-driven systems engineering tool.
5) Install a new version of software into the EASE cloud using the Workflow System while defining its configuration parameters.
6) Link a new configuration element to the capability and execution using the Deploy Asset Management.
7) Execute the simulation through the web-based EASE interview.

8) Access the simulation data as a typical M&S user as opposed to a M&S system engineer.

At the completion of the four-hour hands-on scenario, the post REP survey questionnaire was passed out to each participant. Prior to passing out the survey, I gave brief instructions on the purpose of the survey and how to fill it out. I also, instructed that the survey was completely voluntary and for the participants not to write their names on the questionnaire as per the approval conditions of the Internal review Board (IRB). The participants were given 45 minutes to complete the survey and were instructed to drop off their survey in a box located by the door as they departed the testing area in order to maintain their anonymity. There was a 100 percent response rate for completion and turn-in of the survey.

Index of Sample Population Responses

Although the participants filled out both an evaluation matrix located in Appendix J and a post REP survey questionnaire located in Appendix D, only the comprehensive data in the post REP survey were analyzed to develop answers to the research questions. The remaining appendix J data was provided to the program manager for their technical and programmatic consideration.

In order to analyze the comprehensive data, four indexes were created from the responses using the IBM SPSS statistics software:

1) Exposed to interoperability challenges on a routine basis (ETI).
2) Perceived EASE as a technical solution to interoperability (PTS).
3) Perceived EASE as a managerial solution to interoperability (PMS).
4) Perceived EASE as a knowledge management solution to interoperability (PKMS).

To create the index for the exposed to interoperability, the response scores from the survey questions 1-7 and 15-17 were added together in order to create a new variable in SPSS. The below figure is the SPSS screen capture of creating the Index exposed to interoperability.

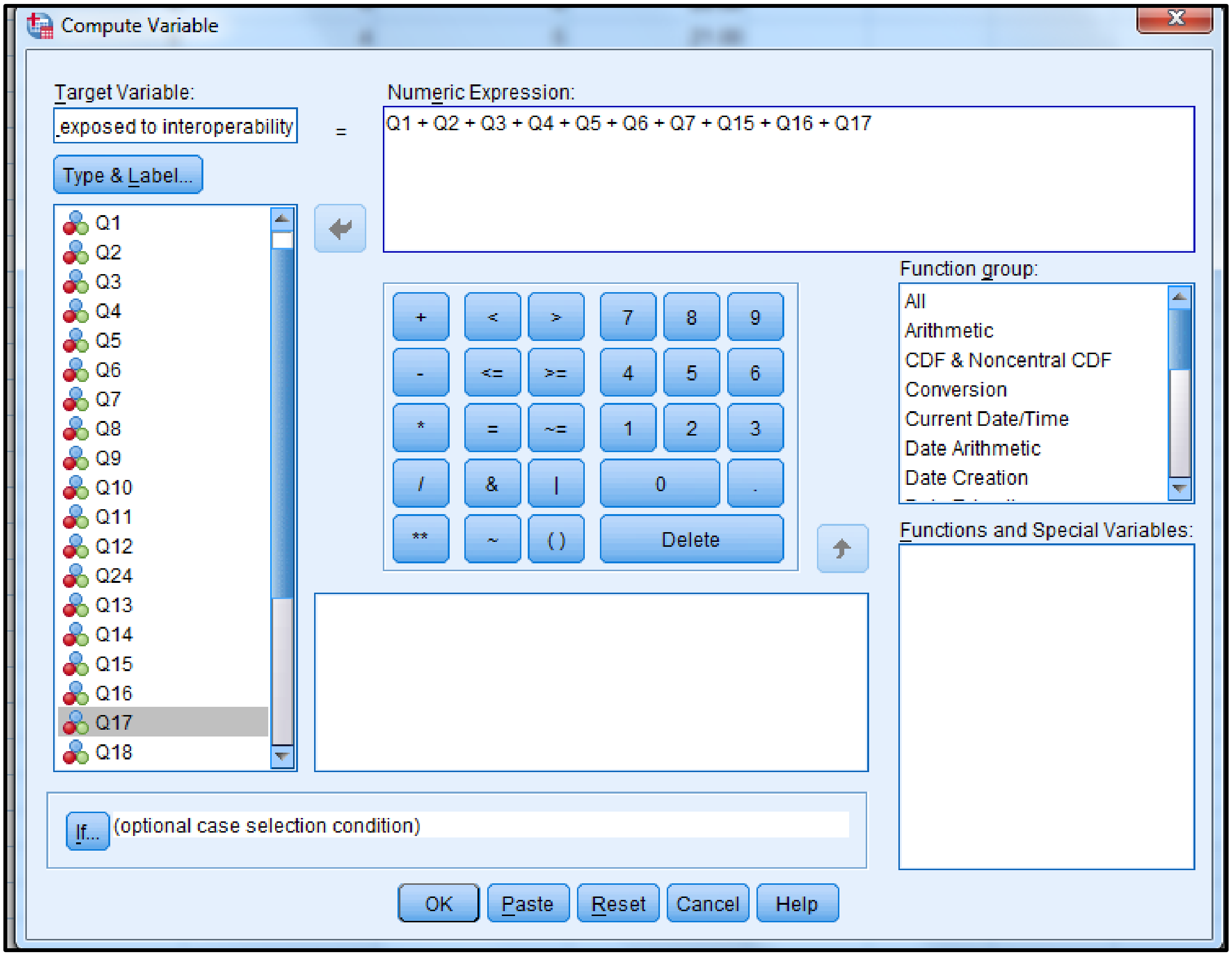


Figure 14: SPSS Screen Capture of Creating the Index of Participants Exposed to Interoperability Variable

The remaining three indexes were created using a similar technique with SPSS. The responses from questions 8-12 and 24 were added together to create the PTS variable. The PMS variable was created by adding together the scores from the responses from questions 13, 14, 18, and 25. The scores from questions 19-21 and 23 were added together to create the PKMS. The below table summarizes the scores from the survey questions that were added together to create the respective index.

Table 5: Summary of Index Variables

Survey Question	Index Name	Index Variable Name
1-7, 15-17	Exposed to interoperability challenges on a routine basis	ETI
8-12, 24	Perceived EASE as a technical solution to interoperability	PTS
13, 14, 18, 25	Perceived EASE as a managerial solution to interoperability	PMS
19-21, 23	Perceived EASE as a knowledge management solution to interoperability	PKMS

Reliability of Sample Population Responses

Davis's TAM was adapted to capture the participants' views on their likelihood of experiencing interoperability challenges and their views on using EASE to mitigate these interoperability challenges. These views were categorized into four areas represented by the four created index variables. The Cronbach Alpha Test for Reliability was used to test the reliability of the adapted TAM. The decision to use the Cronbach Alpha Test was based on the test's versatility and its ability to measure internal consistency on Likert-type responses (Schuyler, 2012). The IBM SPSS software was used to calculate the Cronbach alpha coefficient. The larger the alpha coefficient corresponds with stronger the reliability. As a common rule of thumb, alpha coefficients of 0.5 or less are unacceptable for consistency (George & Mallery, 2003) (Kline, 1999). The below table is the general accepted scale for describing internal consistency:

Table 6: Cronbach's alpha Internal Consistency Description

Cronbach's alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

The calculated alpha for the ten questions associated with the index of Exposed to Interoperability (ETI), the six questions for the index PTS, and the four questions that comprised the index PKMS were all acceptable. The internal consistency for the four questions that were used to formulate the index PMS was questionable. The below four figures are the screen captures of the SPSS results depicting the Cronbach's alpha for the four indexes.

Reliability

[DataSet1] E:\Thesis\Survey Result.sav

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	11	100.0
	Excluded[a]	0	.0
	Total	11	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.719	10

Figure 15: SPSS Screen Capture of the ETI index alpha

Reliability

[DataSet1] E:\Thesis\Survey Result.sav

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	11	100.0
	Excluded[a]	0	.0
	Total	11	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.765	6

Figure 16: SPSS Screen Capture of the PTS index alpha

Reliability

[DataSet1] E:\Thesis\Survey Result.sav

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	11	100.0
	Excluded[a]	0	.0
	Total	11	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.652	4

Figure 17: SPSS Screen Capture of the PMS index alpha

Reliability

[DataSet1] E:\Thesis\Survey Result.sav

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	11	100.0
	Excluded[a]	0	.0
	Total	11	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.765	6

Figure 18: SPSS Screen Capture of the PKMS Index alpha

The below table summarizes the reliability of the four indexes.

Table 7: Summary of the Reliability of the Four Indexes

Index Name	Number of Items	Cronbach's alpha	Internal Consistency
ETI	10	0.719	Acceptable
PTS	6	0.765	Acceptable
PMS	4	0.652	Questionable
PKMS	4	0.791	Acceptable

Analysis of the quality of participants

The participants' experience to interoperability at their respective organizations was measured by analyzing the scores from their responses to the ten questions that comprised the index ETI. The purpose of these questions was to gage the level of the participant's exposure to interoperability to ensure valid test subjects were selected to participate in the experiment.

All the participants, selected in this research, work in the highly niche field of U.S. Army modeling and simulations. However, in order to be a valid test subject, the participants must have some level of exposure to interoperability. To analyze the quality of participants, the following hypothesis was developed:

H_o = The participants are not exposed to interoperability challenges at their organizations.

H_a = The participants are exposed to interoperability challenges at their organizations.

To investigate this hypothesis, each participant was asked to express the strength of his/her response to the ten questions using the seven point Likert scale shown in Table 4 in Chapter 3. An index was created using the responses to the ten questions. A one-sample non-parametric test using the Wilcoxon Signed Rank test from the IBM SPSS statics software was used to compare the index median to the hypothesized median. A response of "4" or less represents a perception of non-exposure from each participant for each question. Since there were ten questions used to calculate the ETI index, the hypothesized median was set to 40. The SPSS calculated ρ value was less than .05 with an observed β less than .001, see figure 19 below for a SPSS screen capture of the calculated ρ value. G*Power was used to calculate the post hoc β (Faul, Erdfelder, Buchner, & Lang, 2009).

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of Index_Exposed_to_Int equals 40.00.	One-Sample Wilcoxon Signed Rank Test	.003	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 19: Wilcoxon Signed Rank test of the Index Exposed to Interoperability

The next figure is a graphical representation of the SPSS Wilcoxon signed rank test.

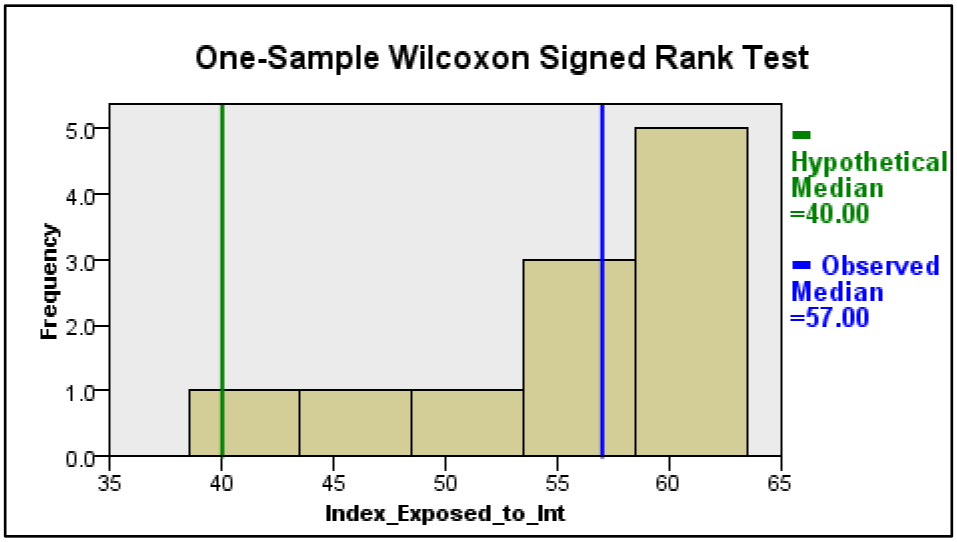


Figure 20: Graphical Representation of the Wilcoxon Signed Rank Test of the Index Exposed to Interoperability

The dimension of ETI was statistically greater than the hypothesized median, which supports the rejection of the null hypothesis that the participants are not exposed to interoperability challenges at their organizations. This supports the claim that the participants were valid test subjects for this research.

Analysis of Research Questions

Research Question 1 (Level that EASE mitigates the local (micro) technical interoperability challenges)

The participants' perception of EASE as a potential solution to mitigate local technical interoperability challenges was measured by analyzing their responses to the six questions that comprised the index PTS. The purpose of these questions was to provide data to answer research question one.

RQ1: At what level does EASE mitigate the local (micro) technical interoperability challenges by enabling the set-up, execution, and documentation of M&S events? If deemed inadequate, what micro technical challenges must EASE solve in order to benefit the M&S community?

H_{o1} = Expert stakeholders believe the EASE prototype does not have potential as a U.S. Army technical solution to help mitigate the M&S interoperability challenge.

H_{a1} = Expert stakeholders believe the EASE prototype does have potential as a U.S. Army technical solution to help mitigate the M&S interoperability challenge.

To investigate this hypothesis, each participant was asked to express the strength of his/her response to the six questions using the seven point Likert scale shown in Table 4 in Chapter 3. An index was created using the responses to the six questions. A one-sample non-parametric test using the Wilcoxon Signed Rank test from the IBM SPSS statics software was used to compare the index median to the hypothesized median. A response of "4" or less represents a less than positive perception of EASE a potential solution to mitigate the local technical challenges of interoperability. Since there were six questions used to calculate the RQ1 index, the hypothesized median was set to 24. The SPSS calculated ρ value was less than .05 with an observed β of .030, see figure 21 below for a SPSS screen capture of the calculated ρ value.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of Index_RQ1 equals 24.00.	One-Sample Wilcoxon Signed Rank Test	.003	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 21: Wilcoxon Signed Rank test of the Index RQ1

The next figure below is a graphical representation of the SPSS Wilcoxon signed rank test for the index PTS.

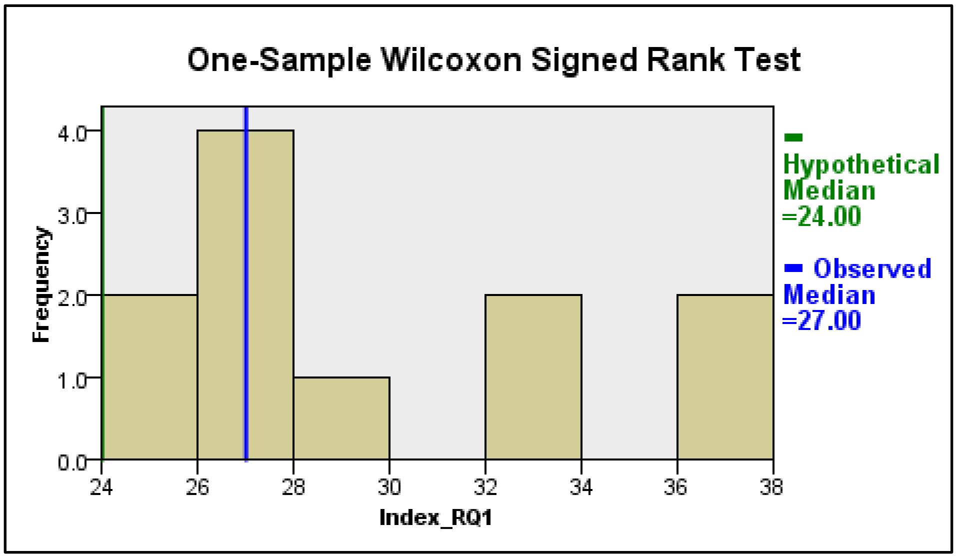


Figure 22: Graphical Representation of the Wilcoxon Signed Rank Test of the Index RQ1

The dimension of PTS was statistically greater than the hypothesized median, which supports the rejection of the null hypothesis that the participants perceive the EASE prototype as not having the potential as a U.S. Army technical solution to help mitigate the M&S interoperability challenge at their organizations. This supports the alternate hypothesis that expert stakeholders believe the EASE prototype does have the potential as a U.S. Army technical solution to help mitigate the M&S interoperability challenge.

Research Question 2 (Level that EASE mitigates the local (micro) managerial interoperability challenges)

The participants' perception of EASE as potential solution to mitigate local managerial interoperability challenges was measured by analyzing their responses to the four questions that comprised the index PMS. The purpose of these questions was to provide data to answer research question two.

RQ2: At what level does EASE mitigate the local (micro) managerial interoperability challenges by enabling the set-up, execution, and documentation of M&S events? If deemed inadequate, what local managerial challenges must EASE solve in order to benefit the M&S community?

H_{o2} = Expert stakeholders believe the EASE prototype does not have potential as a U.S. Army managerial solution to help mitigate the M&S interoperability challenge.

H_{a2} = Expert stakeholders believe the EASE prototype does have potential as a U.S. Army managerial solution to help mitigate the M&S interoperability challenge.

To investigate this hypothesis, the similar technique used to analyze PTS was applied. Each participant was asked to express the strength of his/her response to the four questions using the seven point Likert scale shown in Table 4 in Chapter 3. An index was created using the responses to the four questions. A one-sample non-parametric test using the Wilcoxon Signed Rank test from the IBM SPSS statics software was used to compare the index median to the hypothesized median. A response of "4" or less represents a less than positive perception of EASE a potential solution to mitigate the local managerial challenges of interoperability. Since there were four questions used to calculate the PMS index, the hypothesized median was set to 16. The SPSS calculated ρ value was less than .05 with an observed β less than .001, see figure 23 below for a SPSS screen capture of the calculated ρ value.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of Index_RQ2 equals 16.00.	One-Sample Wilcoxon Signed Rank Test	.005	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 23: Wilcoxon Signed Rank test of the Index PMS

The next figure below is a graphical representation of the SPSS Wilcoxon signed rank test for the index PMS.

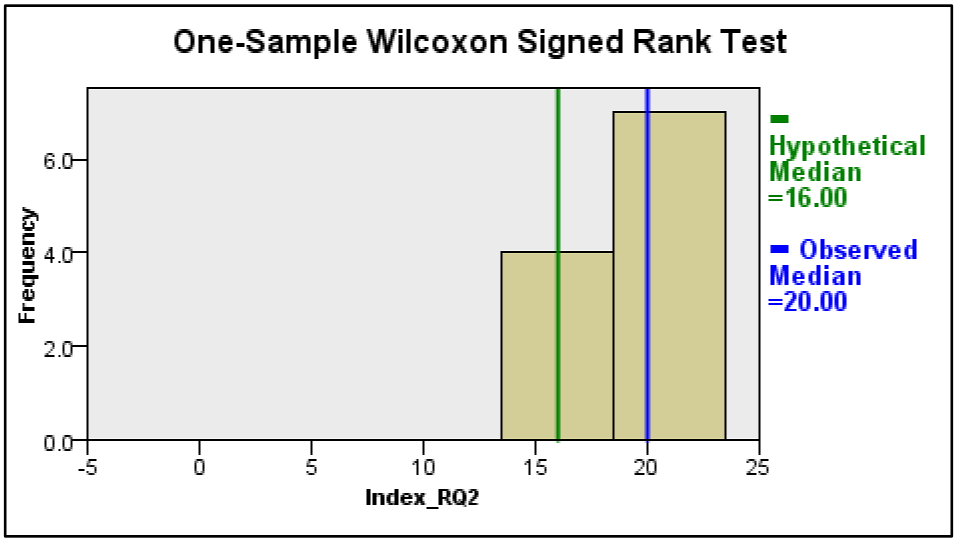


Figure 24: Graphical Representation of the Wilcoxon Signed Rank Test of the Index PMS

The dimension of PMS was statistically greater than the hypothesized median, which supports the rejection of the null hypothesis that the participants perceive the EASE prototype as not having the potential as a U.S. Army managerial solution to help mitigate the M&S interoperability challenge at their organizations. This supports the alternate hypothesis that the expert stakeholders believe the EASE prototype does have potential as a U.S. Army managerial solution to help mitigate the M&S interoperability challenge.

Research Question 3 (Level that EASE mitigates the knowledge management interoperability challenges)

The participants' perception of EASE as potential solution to mitigate the knowledge management interoperability challenges was measured by analyzing their responses to the four questions that comprised the index PKMS. The purpose of these questions was to provide data to answer research question three.

RQ3: At what level does EASE mitigate the knowledge management (KM) challenge of interoperability solutions caused by the short life cycle of personnel and contract support personnel? If deemed inadequate, what specific KM challenges does EASE must address in order to benefit the M&S community?

H_{o3} = Expert stakeholders believe the EASE prototype does not have potential as a U.S. Army knowledge management solution to help mitigate the M&S interoperability challenge.

H_{a3} = Expert stakeholders believe the EASE prototype does have potential as a U.S. Army knowledge management solution to help mitigate the M&S interoperability challenge.

To investigate this hypothesis, the similar technique used to analyze PTS and PMS was applied. Each participant was asked to express the strength of his/her response to the four questions using the seven point Likert scale shown in Table 4 in Chapter 3. An index was created using the responses to the four questions. A one-sample non-parametric test using the Wilcoxon Signed Rank test from the IBM SPSS statics software was used to compare the index median to the hypothesized median. A response of "4" or less represents a less than positive perception of EASE a potential solution to mitigate the local managerial challenges of interoperability. Since there were four questions used to calculate the PKMS index, the hypothesized median was set to 16. The SPSS calculated ρ value was less than .05 with an observed β of .041, see figure 25 below for a SPSS screen capture of the calculated ρ value.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of Index_RQ3 equals 16.00.	One-Sample Wilcoxon Signed Rank Test	.008	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 25: Wilcoxon Signed Rank test of the Index PKMS

The next figure below is a graphical representation of the SPSS Wilcoxon signed rank test for the index RQ3.

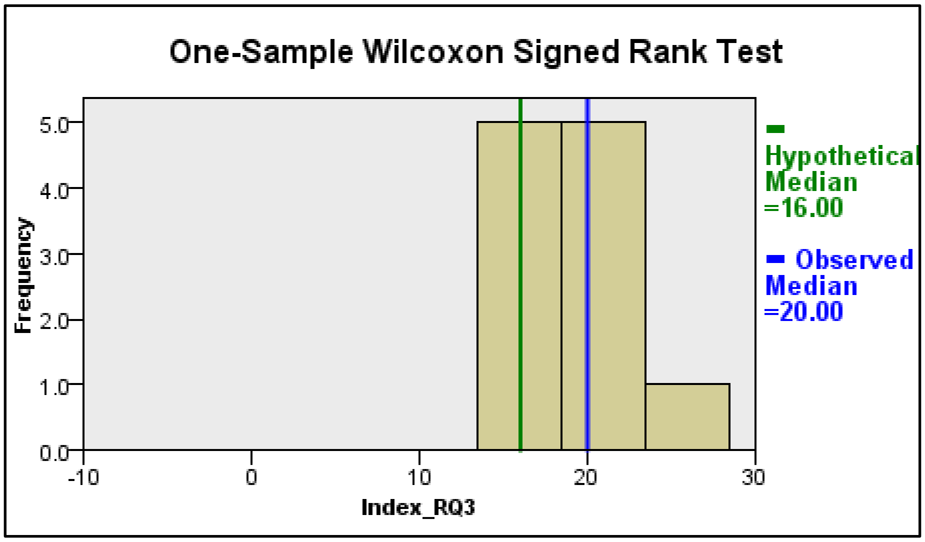


Figure 26: Graphical Representation of the Wilcoxon Signed Rank Test of the Index PKMS

The dimension of RQ3 was statistically greater than the hypothesized median, which supports the rejection of the null hypothesis that the participants perceive the EASE prototype as not having the potential as a U.S. Army knowledge management solution to help mitigate the M&S interoperability challenge at their organizations. This supports the alternate hypothesis that the EASE prototype does have potential as a U.S. Army knowledge management solution to help mitigate the M&S interoperability challenge.

Although all three dimensions of perception of EASE as a potential solution to mitigate interoperability challenges (technical (PTS), managerial (PMS), and knowledge management (PKMS)) were positive, the perception of EASE as a technical solution ranked the highest based on the statistical significance. The perceived use of EASE as a potential solution to mitigate the managerial challenges was higher than the perception of using EASE as a potential solution to mitigate the knowledge management challenges. A thorough discussion of these differences in perception on the three dimensions of EASE as a potential solution to mitigate interoperability will be presented in chapter 5.

CHAPTER 5: SUMMARY AND CONCLUSIONS

Chapter 5 Abstract

This chapter provides a summary of the research and reviews the motivation that drove the experiment. This chapter also reviews the experiment design, data collection, analysis, and findings. A significant portion of the chapter is dedicated to discussing the insights discovered as a result of conducting the research. These insights include strengths and weaknesses of the EASE prototype, on quality of the participants selected, and the research questions. The chapter concludes with future research suggestions that focus on evaluating EASE in support of an actual simulation exercise. The purpose of graduating EASE to the next level of evaluation is to provide a venue to apply specific metrics and obtain data that would either support or refute the perception that use of EASE has the capability of mitigating the interoperability challenge.

Summary

Given that no system can anticipate future technological change and the emergence of new systems, the challenge created by interoperability incompatibility will be with units and organizations for the foreseeable future. The EASE experiment has provided preliminary statistical data that indicates that the EASE prototype demonstrates a potential solution to mitigate the managerial, technical, and knowledge management challenges of interoperability. The EASE experiment was an initial step in coordinating with organizations across the Army and DoD for teaming partners, recommendations, and possible users. A recap of the motivation of this research, along with the experiment design, data collection, and analysis are reviewed in the following sections.

Motivation

For over twenty years, U.S. Army has addressed the requirement to interoperate multiple simulations through the creation and management of several simulation architectures. Models and simulations are continually advancing in technology and growing in operational use in order to support the evolving needs of U.S. Army's simulation communities. The U.S. Army has made strides in improving interoperability, but these improvements have been inadequate with the growing technical complexities of interoperability that are necessary to meet the needs of the users arising from advances in technology and resulting emergent systems that suit user needs. The difficulties of interoperating these new technologies and emergent systems with legacy systems has caused Army organizations to develop and implement non-standard, multi-architecture simulation environments repeatedly in order to achieve excellence in anticipated missions. Repeatedly developing and implementing multi-architecture simulation environments is a costly and time consuming way of doing business as illustrated in the 25th Combat Aviation Brigade's 2009 and 2011 Culminating Training Exercises on the Hawaiian Islands. However, due to the continued advancement in technology and increasingly used emergent systems makes interoperating complex simulations of systems of systems a continuous challenge and results in irreproducible simulation environments (Davis & Anderson, 2004) (Henninger A. , Cutts, Loper, Lutz, Saunders, & Swenson, 2008).

Understanding the continuum of complexity of interoperability, as requirements or needs, helps determine why the previous funding and technical efforts have been inadequate in mitigating the interoperability challenges within U.S. Army simulations. Some of these efforts include creating large simulation federations, overarching simulation integrating architectures, and databases. As the U.S. Army's simulation program continues to evolve while the military and contractor personnel turnover rate remains, for the most part constant, a method of capturing and passing on the tacit knowledge from one personnel staffing life cycle to the next must be developed in order to economically and quickly reproduce complex simulation events.

A potential solution to this challenge is the Executable Architecture Systems Engineering (EASE) research project. The EASE project uses five unique components to provide an easy-to- use interface giving M&S users an improved way to configure and execute M&S events while storing the technical design. However, the main drawbacks to EASE is that it is still in the prototype stage and its potential has not been tested and evaluated as a simulation tool. The focus of this research was to test and assess EASE as a potential tool to reduce the local cost of achieving interoperability.

Design

The experiment focused on three specific areas: managerial, technical, and personnel life cycle challenges. These three focus areas generated five research questions (RQ) that address EASE's limitations as a solution to the U.S. Army's simulation interoperability challenge. Analysis of the research questions was based on frequency and inferential statistics of the participant responses to the experiment questionnaire. The Wilcoxon signed rank-test was performed using the IBM SPSS statistics software. The experiment questionnaire was designed with closed and open form questions focusing on technical performance of EASE and the perceptions of the potential benefits of EASE. The perception response collection was based on the Technology Acceptance Model (TAM) developed by Davis and validated by Davis, Bagozzi, and Warshaw in 1989. The response levels for questions were collected using the seven-level Likert scale.

Five research questions were considered in this research as listed below, but the basis of the EASE experiment was to answer the first three research questions only:

RQ1. At what level does EASE mitigate the local (micro) technical interoperability challenges by enabling the set-up, execution, and documentation of M&S events? (Data collected and analysis performed.)

RQ2. At what level does EASE mitigate the local (micro) managerial interoperability challenges by enabling the set-up, execution, and documentation of M&S events? (Data collected and analysis performed.)

RQ3. At what level does EASE mitigate the knowledge management (KM) challenge of interoperability solutions caused by the short life cycle of personnel and contract support personnel? (Data collected and analysis performed.)

RQ4. At what level does EASE mitigate the DoD wide (macro) technical interoperability challenges by enabling the set-up, execution, and documentation of M&S events? If deemed inadequate, what macro technical challenges must EASE solve in order to benefit the M&S community? (Beyond the scope of this research.)

RQ5. At what level does EASE mitigate the DoD wide (macro) managerial interoperability challenges by enabling the set-up, execution and documentation of M&S events? If deemed inadequate, what macro managerial challenges must EASE solve in order to benefit the M&S community? (Beyond the scope of this research.)

Data Collection

The target population were subject matter experts (SME) from the M&S community. The sample population was eleven SME's that participated in a three day EASE workshop. The SMEs were invited to participate based on the results of an EASE stake holder analysis on-line survey located in Appendix C. The workshop consisted of both a training session and a practical exercise using EASE. Once the participants completed the practical exercise, they answered a questionnaire consisting of both closed and open ended questions. The questionnaire was designed using a modified form of the Davis's Technology Acceptance Model (1985) to capture the participants' acceptance of the EASE technology in terms of usability and usefulness.

By applying the TAM to the questionnaire, the participants were able to assess the likelihood of experiencing interoperability challenges and express their views on using EASE to mitigate the technical, managerial, and knowledge management interoperability challenges. The indexes exposed to interoperability on a routine basis (ETI), perceived EASE as a technical solution to interoperability (PTS), perceived EASE as a managerial solution to interoperability (PMS), and perceived EASE as a knowledge management solution to interoperability were created to represent these views.

Summary and Analysis

Reliability of the Four Indexes

The Cronbach Alpha Test for Reliability was used to test the reliability of the adapted TAM. The decision to use the Cronbach Alpha Test was based on the test's versatility and its ability to measure internal consistency on Likert-type responses. The IBM SPSS software was used to calculate the Cronbach alpha coefficient. The larger the alpha coefficient corresponds with stronger the reliability. The calculated alpha for the questions associated with the indexes ETI, PTS, and PKMS were all acceptable. The internal consistency was questionable for the questions that were used to formulate the index PMS.

Summary and analysis of EASE as a Perceived Knowledge Management Solution (PKMS)

The participants' perception of EASE as a potential solution to mitigate local technical interoperability challenges was measured by analyzing their responses to the six questions that comprised the index PTS. On the one hand, a statistically significant response of less than the median represents a less than positive perception of EASE as a potential solution to mitigate the local technical challenges of interoperability. On the other hand, a statistically significant response greater than the median represents a positive perception of EASE. A non-statistically significant finding indicates ambivalence about EASE. The actual sample data for the dimension of EASE as a perceived technical solution for interoperability was statistically greater than the hypothesized median. That finding supports rejection of the null hypothesis and acceptance of the alternative hypothesis.

Summary and analysis of EASE as a Perceived Managerial Solution (PMS)

The participants' perception of EASE as a potential solution to mitigate local managerial interoperability challenges was measured by analyzing their responses to the four questions that comprised the index PMS. A statistically significant response of less than the median represents a less than positive perception of EASE as a potential solution to mitigate the local technical challenges of interoperability. However, a statistically significant response greater than the median represents a positive perception of EASE. A non-statistically significant finding indicates ambivalence about EASE. The actual sample data for the dimension of EASE as a perceived managerial solution for interoperability was statistically greater than the hypothesized median. That finding supports rejection of the null hypothesis and acceptance of the alternative hypothesis. Simply put, participants perceive the EASE prototype as having the potential to help mitigate managerial challenges associated with interoperability at their organization.

Summary and analysis of EASE as a Perceived Knowledge Management Solution (PKMS)

The participants' perception of EASE as a potential solution to mitigate knowledge management interoperability challenges was measured by analyzing their responses to the four questions that comprised the index PKMS. A statistically significant response of less than the median represents a less than positive perception of EASE as a potential solution to mitigate the PKMS challenges of interoperability. However, a statistically significant response greater than the median represents a positive perception of EASE. A non-statistically significant finding indicates ambivalence about EASE. The actual sample data for the dimension of EASE as a perceived knowledge management solution for interoperability was statistically greater than the hypothesized median. That finding supports rejection of the null hypothesis and acceptance of the alternative hypothesis.

Findings

Based on statistical analysis using an alpha level of .05, the participants perceive the EASE prototype as having the potential to help mitigate the M&S interoperability challenge at their organization. More specifically, they perceive EASE as a potential solution to the micro technical and managerial and the knowledge management interoperability challenges caused by personnel turn-over, mission requirements, evolving technologies, and continued use of legacy systems. Although the participants perceive EASE as a potential solution, they were apprehensive to the data input required to use EASE for the first time.

A common theme was identified based on the participant's responses to question 26, located in Appendix O. The participants believe that the success of EASE to mitigate their organization's interoperability challenge is directly related to the access of the system engineering (SE) information required for input into the SDD component of EASE. They were concerned that the data normally maintained at the developer level would not be available or they would lack the necessary knowledge to input the data themselves. In the words of one of the participants "...M&S developers would need to populate the SDD/SE data [in order to] facilitate the user's execution." Although EASE reduced the burden of the M&S user of having to repeatedly set up and configure a multi-architecture simulation environment, the initial set-up and decomposition of the simulation capabilities were still required when using EASE.

Insights from the Experiment

Research Questions 4 and 5

As discussed in Chapter 3, research questions four and five exceed the scope of this thesis. However, based on the responses to questions 26-30 on the post hands-on survey questionnaire, insights to RQ4 and RQ5 were revealed. In order for EASE to mitigate the technical and managerial challenges at the macro level, the participants suggest that EASE must be made into a program of record (POR). A common belief among the participants, in order for EASE to make a DoD wide impact, EASE would require a steady funding source and central management consistent with PORs. They also acknowledged that the success of EASE as a POR would be directly dependent upon the systematic release of the front end information from the M&S developers in order to streamline and reduce the encumbrance of populating the SDD.

Strengths of EASE

During the workshop discussions, the participants were asked to identify the key strengths of EASE that will allow the tool to benefit M&S users. The top seven items are listed below:

- Captures interoperability requirements between simulations / tools.

- Captures technical knowledge.
- Maintains repository of M&S, both local and central.
- Simplifies the process of configuring and running applications like Combat XXI.
- Provides central management tool to launch multiple applications from a central point.
- Provides stair-step approach to test/retest; captures test results and allows for rerunning of tests.
- Identifies capability gaps within current model, find other models in the environment, suggest other applications to fill gap.

Weaknesses of EASE

Although the data supports the claim that the EASE prototype has the potential to mitigate the challenges of interoperability associated with technical, managerial, and knowledge management issues, the participants identified a common set of weaknesses during the EASE feedback portion of the seminar. The participants believed EASE would be more useful if it had the ability to automate and generate terrain scenarios for the M&S applications. A concern of the required effort to correlate terrain between simulations was expressed by several participants. The current process requires M&S developers to create and upload the required terrain files.

Another identified drawback to the EASE prototype is the user interface. A common theme among the participants is that the EASE SDD interface in not intuitive and requires "in depth guiding" to navigate properly. The majority of the participants were troubled with the time, effort, and expertise required to initially get the currently used systems and tools configured in the SDD. In addition to the SDD, the participants voiced the reuse of information obtained from past simulations is not as robust as it could be limiting the "value" of the previous exercises.

Improvements for EASE

During the second day of the EASE workshop, the participants developed and rank ordered seven improvements for the EASE prototype into three categories; high, medium, and low priority. There were three improvements identified at the high and medium priority and one improvement at the low priority.

High Priority Improvements:

- Enumeration comparison and mapping - The capability of running an enumeration comparison to include the mapping of the output file in a publish/subscribe matrix for visual comparison.
- EASE use case in support of a study - Develop an EASE scenario using a large scale model like Combat XXI that has the granularity to model smaller areas at higher fidelity and resolution for urban operations. Demonstrated the capability to dynamically change model representations for resolution changes via switching models.
- Link to WebMSDE - Require a M&S domain to adopt the SDD as a common tool and choose two or three common simulation tools as a trial test.

Medium Priority Improvements:

- Parametric data linking - This will address potential "fair fight" issues by establishing a systems engineering tool to determine if the Probability Hit (PH) / Probability Kill (PK) table is adequate.
- Global URN (Unit Reference Number) - The capability of EASE using the global URN / task organization (force builder) for entity building in the scenario creation allowing specific icons on display.

- Align with scenario development tools - Add the capability to EASE to use force builder to generate LDIF (LDAP (Lightweight Directory Access Protocol) Data Interchange Format) specific to an organization.

Low Priority Improvements:

- OneSAF output specific artifacts - The information displayed in the post simulation run artifacts for generated from OneSAF is limited. Create more robust definition of output metrics to include customizable outputs that could be used by analysts.

Suggested Future Research

This initial M&S user community evaluation provided data and insights on the potential benefits of the EASE prototype. The results from this experiment are encouraging and warrant further experimentation of the EASE tool in order to refine the suggested improvements. For future experiments, it is suggested to use a simulation tool the participants are more familiar with such as replacing Situational Awareness Normalization and Dissemination Service (SANDS) with JCATS during the hands-on scenario session. As the EASE prototype matures, frame EASE within a larger context of the M&S domain allowing the participants to relate such as using EASE to support an actual M&S event.

A final suggestion for future research would be to evaluate EASE supporting an M&S organization over the course of three to four M&S events. This would allow a direct comparison of an M&S exercise executed with and without EASE, producing quantifiable metrics in evaluating EASE as a tool to mitigate the interoperability challenge.

APPENDIX A: 2011 CTE EXERCISE COSTS

25th Combat Aviation Brigade

2011 CTE Exercise Costs

25 CAB/TF 3-25/209 ASB (Oahu/BCTC/AVCATT) Live , Virtual, & Constructive	
MCTC / I-HITS / AVCATT Overtime	**~$335K**
AVCATT Overtime	**~ $20K**
TFPS (CH-47F) to AVCATT	**$134K**
TNG SUPPORT PKG (TDY) (Travel, Per Diem, Lodging, Vehicles) 82 CAB (White Cell) from NC (WAAF) 2 CAB from KO (WAAF) JRMC from GE (WAAF & PTA) 449th from NC (BLISS)	**$561K** $ 40K $220K $257K $ 44K
ICE CONTRACT	**$388K**
TOTAL	**~$1.4M**

2-25 (PTA)	
COMM AIR	**$88K**
CTE RANGES	**$25K**
Trash, Latrines, TMP Vehicles	**$45K** $45,420
TOTAL	**$158K**

Movement Costs (A/C & Equip ISO JTF-N)	
STRAT AIR [3EA HH-60s; 1EA OH-58; 1EA UH-60L] ($1.2M per leg {based on use of AN124 or C5})	$2.4M
Vessel Movement/Line haul	**TBD**
TOTAL	**$2.4M**

JRTC Movement Costs (HI to LA)	
STRAT AIR [3EA HH-60s; 7EA UH-60Ls; 12EA OH-58s] ($1.2M per leg; 8 legs {based on use of AN124 or C5})	**~$9.6M**
Vessel Movement	**~$5.0M**
SAM for PAX	**~$1.8M**
A/C Reception (LA) & Return to HS (HI) Travel (Commercial Flight) ($1656 RTx37) + (RTx25) Per Diem ($46*10 days*37 PAX*2) Vehicles (4 *15 PAX Vans & 2*Sedans)	**~$145K** $102,672 $ 34,040 $ 8,000
TOTAL	**~$16.5M**

JRTC Cost Estimate	
TOTAL	**$**

JTF-N	
Equipment Trans Cost	$
Life Support CL I Billeting Vehicles (1*Sedan)	 $ $ $
TOTAL	**$**

1-2ARB TNG	
Equipment Trans Cost	$425K
PAX Trans Cost (Bus)	TBD
Life Support	$338,529K
MRE	$ 10,185
Buses	$ 4,500
Dumpsters	$ 7,910
Light Sets	$ 20,112
Tents (w/45KW Generators)	$187,210
Latrines	$ 5,470
Rental Vehicles	$ 12,142
Utilities	$ 91,000
TOTAL	**~$764K**

A/C XFER (JBLM) 4 PAX	
A/C XFER Travel (Commercial Flight) ($2086 RTx4) Billeting ($90*4 nights) = $360 Per Diem ($46*5 days) = $230 Vehicles (1*Sedan)	$10, 954 $8,344 $1,440 $ 920 $ 250
TOTAL	**~$11K**

A/C XFER (HOOD) 7;16 PAX	
A/C XFER (2 Inspections) Travel (Commercial Flight) ($2086 RTx7) + ($1043 OW x 16) Billeting ($90*4 nights) = $360 Per Diem ($46*5 days) = $230 Vehicles (2*Sedans)=$1175x3	$48,385 $31,290 $ 8,280 $ 5,290 $ 3,525
TOTAL	**~$49K**

CAB Cost: ~$4.0 Million

Total Cost: ~$21.3M

Blue= CAB Cost Orange=4-25 Cost Green= AMCOM Cost Red=JTF-N Cost Turquoise=FORSCOM Cost

UNCLASSIFIED//FOUO

(Barry, 2011)

APPENDIX B: AIR WORTHINESS RELEASE (AWR)

DEPARTMENT OF THE ARMY
US ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND
AVIATION AND MISSILE RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER
5400 FOWLER RD
REDSTONE ARSENAL, AL 35898-5000

REPLY TO
ATTENTION OF

RDMR-AER-B 10 May 11 R1

MEMORANDUM FOR Kiowa Warrior Product Office (SFAE-AV-ASH-KW)

SUBJECT: Airworthiness Release (AWR) for the Operation of the OH-58D Helicopter with the Tactical Engagement Simulation System (TESS) Instrumentation Kit Installed. (TN 90010R1)

1. Scope: This Memorandum constitutes an AWR in accordance with (IAW) Army Regulation (AR) 70-62 authorizing the OH-58D Helicopter to conduct Flight operations with the TESS Instrumentation Kit Installed.

2. Validity: **This AWR supersedes AWR 90010 dated 17 Nov 10**, and terminates upon a change in the aircraft hardware, Full Authority Digital Electronic Control (FADEC) software, or issuance of a later AWR whichever occurs first.

3. Appendices: This memorandum and appendix A shall be carried in the logbook, and complete AWR copy with all appendices kept in the aircraft historical record file.

Appendix A Restrictions and Operating Information
Appendix B Configuration and Installation Detail
Appendix C Inspections, Maintenance, and Logbook Instructions
Appendix D Reference List

4. The point of contact is Ed Mueller, AMSRD-AMR-AER-B, DSN 897-2393, commercial (256) 313-2393, or E-mail Ed.Mueller@us.army.mil. Or Mr. Jesse Gutierrez, Camber Contractor, at (256) 313-2401, DSN 897-2401, e-mail: jesse.gutierrez@us.army.mil.

Encls

WILLIAM D. LEWIS
Director
Aviation Engineering

APPENDIX C: ONLINE EASE SURVEY

Survey Questions for stakeholder's analysis:

1. How many years of experience do you have using combat simulations?
2. What best describes your current role as it relates to M&S?
3. Please list your organization.
4. How frequently does your organization use simulation?
5. How would you classify the importance of combat simulation to accomplishment of your organizations day to day mission?
6. What best describes the primary use of M&S for your organization?
7. What Simulation packages does your current organization use?
8. What are the biggest limitations of the simulation tools you currently use?
9. What is the typical duration of Modeling and Simulation phases for an M&S event?
10. Has your organization ever used a distributed simulation approach?
11. How frequently does your organization use distributed simulation?
12. What is the typical Classification level at which your organization conducts M&S work?
13. How Important is Verification, Validation, & Accreditation with respect to your organizations use of M&S?
14. Are all the M&S tools you currently use Verified, Validated, & Accredited?
15. From your perspective, rank order the importance of the following criteria with respect to a combat simulation package (1 being most important,7 being least important):
Use each ranking only once
    - Low barrier to use for varying M&S skill levels
    - Ability to Access and Run from anywhere
    - Integrates with other commonly used M&S Packages or Scripts
    - Powerful and customizable output graphics and statistics
    - Front end DOE capability to plan and customize experiments
    - Ability to add and modify scenarios
    - Ability to interface with and draw from authoritative data sources
16. What M&S pre-processing tools do you commonly use?
17. What M&S post-processing tools do you commonly use?
18. How many engineers are involved in your typical simulation event?
19. How often are your simulation models changed (including data, configuration, design, or algorithms)?
20. How often do you develop new scenarios for your simulations?
21. How many people are typically involved in creating new scenarios?
22. What standard/format is used to digitally save your scenarios?
23. Are humans required to interact with your typical simulation during its run for pucking, monitoring, etc?
24. How much time is does it typically take to initialize a simulation once it has been developed for use (assumes data already loaded)?
25. How are your Simulations executed?
26. Does it sound as if something like EASE would meet some of your organization's M&S needs?

27. From your perspective, incorporation of what features or functionality into EASE would increase your likelihood of use?
28. Are you aware of any other organization or agency working an effort similar to EASE?
29. EASE can incorporate the use of surrogates in a simulation. Surrogates are plug and play modules that replicate essential model components that are currently not available. Could you use the surrogate functionality?
30. Would you need a new Certificate of Net worthiness to run something like EASE?
31. How difficult would it be to get a new CON?
32. After EASE is fully developed, who do you think is the most appropriate organization to "own" and maintain it.
33. What specific capabilities (i.e communications effects, etc.), most beneficial to your organization, would you like to see incorporated into EASE?
34. If you would like to make any comments on the topics of this survey or any other M&S topic of interest to you and/or your organization that were not addressed in this survey, please type them in the space below.

APPENDIX D: POST EASE HANDS-ON SURVEY QUESTIONNAIRE

Table 8: Post EASE Experiment Survey Questionnaire

User Category:	Organization:	Years of M&S Experience:						
Category Options: **1 - Systems Engineer** **2 - Federation Manager** **3 - Developer** **4 - Management** **5 - Scenario Designer**		**Response Scale:** **1- Extremely Unlikely** **2- Quite Unlikely** **3- Slightly Unlikely** **4- Neither Likely or Unlikely** **5- Slightly Likely** **6- Quite Likely** **7- Extremely Likely**						
		Response						
		1	**2**	**3**	**4**	**5**	**6**	**7**
1. How likely is my organization to frequently change its simulation models (including data, configuration, design, or algorithms)?								
2. How likely is my organization to develop new scenarios for our simulations?								
3. How likely is my organization to invest significant amounts of time duplicating simulation architecture in order to complete its mission?								
4. How likely is easily creating interoperability among simulation tools is a concern for my organization?								
5. How likely would a tool that could increase the level of interoperability among simulation tools benefit my organization?								
6.How likely would a tool that could document simulation event technical designs and then reproduce them benefit my organization?								
7. After evaluating EASE, how likely would you be willing to test it in an actual simulation event?								
8. How likely do you think the SDD component of EASE would correctly produce the data decomposition requirements and system architecture guidelines from a given set of simulation event modeled capabilities in my M&S environment?								
9. How likely do you think the Deploy Asset Management and Workflow System would correctly install the software so that the binaries would be located in the repository file in my M&S environment?								
10. How likely do you think the Deploy Asset Management and Workflow System would correctly execute the Configuration Decompositions to include the Mode (HLA/TENA/DIS/CTIA), performance data, and scenario in my M&S environment?								
11. How likely do you think the Interview Management Component would execute a successful simulation run and the VM is streamed to a webpage in my M&S environment?								
12. How likely do you think EASE will support the development and creation of new scenarios?								
13. How likely do you think the EASE prototype would capture the SQL exports, software/application files, and video files accessible by users in my M&S environment?								
14. How likely do you think EASE will support the analysis of data?								
15. How likely is my organization to make internal and custom interoperability modifications to simulation releases?								
16. How likely were you able to use lessons learned on each modification based on subsequent modifications?								
17. If you were able to use lessons learned from the previous modification, how was that possible:								
a. Same contractor?								
b. Same organization personnel?								

User Category:	Organization:	Years of M&S Experience:						
Category Options: **1 - Systems Engineer** **2 - Federation Manager** **3 - Developer** **4 - Management** **5 - Scenario Designer**		**Response Scale:** **1- Extremely Unlikely** **2- Quite Unlikely** **3- Slightly Unlikely** **4- Neither Likely or Unlikely** **5- Slightly Likely** **6- Quite Likely** **7- Extremely Likely**						
		Response						
		1	**2**	**3**	**4**	**5**	**6**	**7**
d. Same problem? e. All?								
18. If interoperability is a challenge, how likely would the EASE tool reduce the cost of the interoperability modification that your organization requires?								
19. If interoperability is a challenge, how likely would the EASE tool reduce the time of the interoperability modification?								
20. If interoperability is a challenge, how likely would the EASE tool reduce the personnel cost of the interoperability modification?								
21. How likely do you think the EASE tool can help mitigate lost simulation knowledge due to M&S personnel leaving your organization?								
22. How likely will my organization go through interoperability issues that require hiring a contractor to fix?								
23. If interoperability is a challenge, how likely would the EASE tool reduce the impact of my organization's personnel turn-over?								
24. If EASE was made a program of record, how likely will the EASE concept mitigate the DoD wide (macro) TECHNICAL interoperability challenges by enabling the set-up, execution, and documentation of M&S events?								
25. If EASE was made a program of record, how likely will the EASE concept mitigate the DoD wide (macro) MANAGERIAL interoperability challenges by enabling the set-up, execution, and documentation of M&S events?								
26. How likely do you think EASE can reduce the interoperability challenges in my organization? *Explain Answer in comments section.								
Free Response Survey Question: use comments section for answer								
27. What function of EASE is most beneficial?								
28. What functions should be added to EASE?								
29. What are the main simulation interoperability challenges in my organization?								
30. In the space below, make any additional comments on the survey topics or any other M&S issue of interest.								
Comments Section								

APPENDIX E: SAMPLE OUTPUT FROM SDD TESTS (SEQUENCE DIAGRAM, MDD, AND M&S FUNCTIONS)

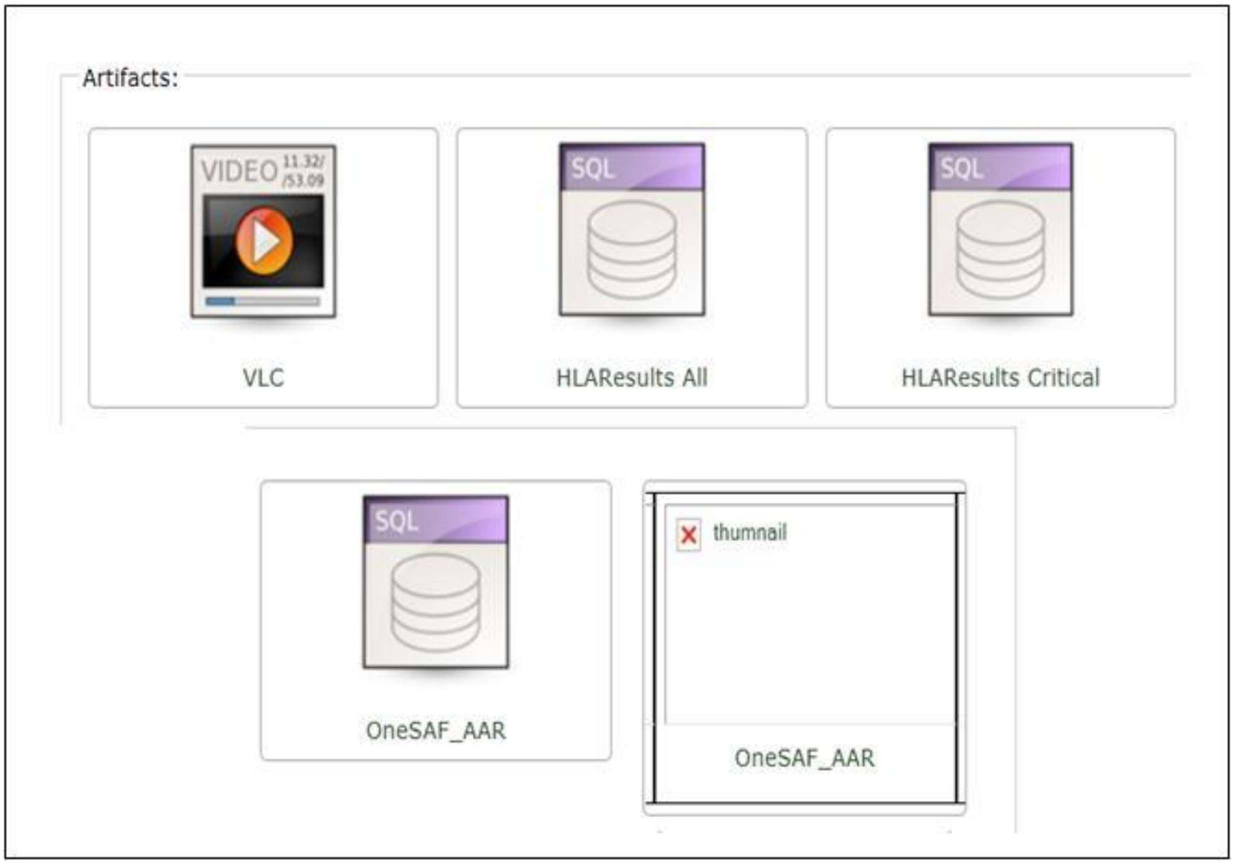
MDD	Function	Realized	Participating	Implemented	Allocated
	2D/3D Display of Ground Truth			✓	✓
	2D/3D Display of Perceived Truth			✓	✓
	Air platform implementor			✓	✓
	Air Support Operations Center - ASOC			✓	✓
	Aircraft Representation			✓	✓
	Area of Operation Initialization			✓	✓
	Areas of Operation Management			✓	✓
	Ballistic Fire Solution Implementor			✓	✓
	Ballistic Projectile Representation			✓	✓
	Ballistic Shooter			✓	✓
	Battalion Operations Gateway (BN_OPSGW)			✓	✓
	Battalion S3 Maneuver Control System (BN_S3MCS)			✓	✓
	Battallion Fire Effects Cell - (BN FECC)			✓	✓
	Blue SA Init Handler		✓		
	Blue SA Request Handler		✓		✓

APPENDIX F: SAMPLE OUTPUT FROM SDD TESTS (TECHNICAL SOLUTION DIAGRAM PUBLISH/SUBSCRIBE MATRIX)

Objects	NVIG	NCBR	OASES	OneSAF
AGM				
AOPolicy				
Aircraft				P
C3Nodes				
EffectsGuidance				
EnvironmentProcess		P		
Field	S			
GUIDANCE				
GriddedData		P		
GroundPlatform				P
ISRReportingPolicy				
IndividualCombatant				P
LaneMarkings	S			
MissionValueGuidance				
Munition				
Platform	S			PS
TASKO				
UGS				
Uniform_Atmosphere			P	

Components

APPENDIX G: SAMPLE OUTPUT FROM THE DEPLOY ASSET MANAGEMENT AND WORKFLOW SYSTEM TESTS (ARTIFACTS FROM A SMALL ARMS ENGAGEMENT SCENARIO)


Artifacts:
VIDEO 11.32/ /53.09
SQL
SQL
VLC
HLAResults All
HLAResults Critical
SQL
thumnail
OneSAF_AAR
OneSAF_AAR

APPENDIX H: PARTICIPANTS OF THE RESEARCH EXECUTION PHASE (REP)

Reps	Organization Name	Short Name	Location	Domain
1	Mission Training Complex - Fort Hood	MTC-Hood	FT Hood, TX	TEMO
1	Mission Training Complex - Fort Stewart	MTC-Stewart	FT Stewart, GA	TEMO
1	Mission Training Complex - Fort Riley	MTC-Riley	FT Riley, KS	TEMO
1	United States Military Academy	USMA	West Point, NY	TEMO
1	Joint Mission Environment Test Capability / Test Resource Management Center	JMETC/TRMC	Washington D.C.	RDA
1	U.S. Army Materiel Systems Analysis Activity	AMSAA	Aberdeen Proving Ground, MD	RDA
1	U.S. Army Test and Evaluation Command Operational Test Command	ATEC OTC	FT Hood, TX	RDA
1	U.S. Army Capabilities Integration Center	ARCIC	FT Eustis, VA	ACR
1	U.S. Army Maneuver Support Center of Excellence	MSCoE	FT Benning, GA	ACR
2	U.S. Army TRADOC Analysis Center - Fort Leavenworth	TRAC-FLVN	FT Leavenworth, KS	ACR

APPENDIX I: EASE WORKSHOP SCHEDULE

24-Oct-12

Time	Event	Location	Lead/Assist
1230-1300	Registration	DAS Suite 436	Lesinski
1300-1320	Admin/Intro	DAS Suite 436	Lesinski/Gaughan
1320-1500	Organization Briefs	DAS Suite 436	Lesinski / Attendees
1500-1515	Break		
1515-1530	EASE Overview	DAS Suite 436	Gaughan
1530-1555	ATC Demonstration	DAS Suite 436	Pettiford
1555-1630	SDD Demonstration	DAS Suite 436	Gallant
1630-1710	Interview slides/demo	DAS Suite 436	Gallogly
1710-1735	Cloud slides / demo	DAS Suite 436	Murphy
1735-1740	Wrap-up	DAS Suite 436	Lesinski
1830-	Dinner/Social	Mellow Mushroom	Lesinski

25-Oct-12

Time	Event	Location	Lead/Assist
0900-0915	Admin	DAS Suite 436	Lesinski
0915-1200	Workshop - Hands On	DAS Suite 436	EASE Tech Team
1200-1315	Lunch	The Moat	Lesinski
1315-1430	Complete EASE Hands-On	DAS Suite 436	EASE Tech Team
1430-1515	EASE Survey	DAS Suite 436	Barry
1515-1530	Break		
1530-1700	EASE Feedback	DAS Suite 436	Lesinski/Gallant
1800-	Dinner (On own or Group)	Firkin & Kegler	Lesinski

26-Oct-12

Time	Event	Location	Lead/Assist
0900-0915	Admin	DAS Suite 436	Lesinski/Gaughan
0915-1015	M&S Challenges/Priorities	DAS Suite 436	Lesinski
1015-1030	Break		
1030-1130	Invited Presentation on the latest in M&S Interoperability	DAS Suite 436	Dr. Gary Allen LVCAR PM
1130-1200	Wrap-up, Actions	DAS Suite 436	Lesinski

APPENDIX J: REP EVALUATION MATRIX

Table 9: EASE Participant Evaluation Matrix

Participant name: **Code: (Filled out by PI):**	Organization:				User Category:
Evaluation Metric	Answer			Additional Comments	
	Yes	Partial	No		
Does the SDD component of EASE correctly produce the data decomposition requirements and system architecture guidelines from a given set of simulation event modeled capabilities?					
Does the SDD component of EASE prototype correctly allocate the appropriate application to the capability components and the appropriate Object Model (OM) elements to the information exchange events to produce a technical solution diagram?					
Does the Deploy Asset Management and Workflow System correctly install the software so that the binaries are located in the repository file?					
Does the Deploy Asset Management and Workflow System correctly execute the Configuration Decompositions to include the Mode (HLA/TENA/DIS/CTIA), performance data, and scenario?					
Does the Interview Management Component correctly link the execution data to the design data?					
Does the Interview Management Component execute a successful simulation run and the VM is streamed to a webpage?					
Does EASE capture the SQL exports, software application files, and video files in its artifacts?					

APPENDIX K: EASE HANDS-ON SCENARIO DOCUMENT

EASE Hands-on Scenario

10/24 – 10/26/2012

This document is for the Executable Architecture Systems Engineering (EASE) Hands-on Scenario Session. EASE is a research project led by the U.S. Army Research Laboratory (ARL) at the Simulation and Training Technology Center (STTC) in Orlando, Florida. The Workshop session is hosted and executed by the United States Military Academy (USMA), LTC John Barry – University of Central Florida, Dynamic Animation Systems, Inc., Effective Applications Corporation and Raytheon.

Introduction to Executable Architecture Systems Engineering (EASE)

Executing M&S is time consuming, technically complex and requires specialized staff. Executable Architecture Systems Engineering (EASE) provides an easy to use interface to allow M&S users to more easily configure and execute modeling and simulation on a cloud-based set of computing resources.

Distributed Modeling and Simulation (M&S) is fundamentally based on the exchange of information between functions that may not have been built to work together. Models are usually separately managed with varying budgets and often with disparate purposes. The life cycle of an M&S event is long due to the complexity of the systems engineering required to design, implement and deploy a cohesive set of systems towards the event's objectives.

Our recent research has focused on developing a tool, EASE, to facilitate the systems engineering phase to enable more accuracy and automation within the implemented event. We have successfully captured the technical specification from requirements through design to execution information (including configuration) in a database-driven and linked manner.

EASE captures high level system requirements and their linkage to low level model specifications. We'll show how we capture metadata about the models, scenarios and execution environment and ultimately how we deploy and execute the specified models using virtual machines. Our system interface includes an electronic interview process that determines which of the many possible implementation choices (models, scenarios and system designs) to use from the users' requirements. Based on the strategy we use for capturing the system design and a Government-owned set of tools, we can also create and rapidly generate surrogate applications to substitute for late, faulty or unavailable models.

These capabilities come together within our initiative, the Executable Architecture Systems Engineering (EASE) for M&S thrust. We'll also mention how the community could benefit from these methodologies and our future research areas.

Simulation users who require the use of distributed simulation typically do not have a long life cycle for an experiment, analysis initiative or simulation-based event. To reduce cost, they need to use a reliable simulation environment and robust models that are easy to integrate with other distributed simulations. This short lead time for system design, development, integration and execution forces the system definition and design to happen very quickly.

These M&S users rely on standards and simulation developers to get the systems to communicate using the same syntax. This often works to instantiate a System of Systems (SoS) architecture and get models to share information. A SoS environment is an assembly of applications that together provide more capability than the sum of their individual capabilities. Within the M&S community, the applications assembled are each focused on representing a specific warfare function based on data and models from an organization considered to be the center of excellence for that function. The SoS architecture provides many benefits when compared to executing a single monolithic model including performance, model management and information transparency for analysis.

However, the biggest problem in these cases is that the models do not work together semantically for the accomplishment of the high level functions that the users require. In other words, applications may not be communicating based on a consistent understanding of the context and connotation of the information being shared. Our prototype tool, EASE, ensures semantic interoperability traced back to functional requirements. We have learned many lessons in our work and see a vision for the future of systems engineering for SoS architectures.

We have established a systems engineering data-driven infrastructure that allows SoS design encapsulation and connected an interview system that allows a user to launch a distributed M&S execution based on functional and scenario choices. We have implemented generative programming techniques (automatically generating executable computer programming artifacts from a higher level source) in order to quickly deploy a SoS architecture for military analysis. The flexibility required to implement our goal requires systems architecture qualities and objectives such as encapsulation of functionality into appropriately sized portions to be able to manipulate and construct larger capabilities as needed with as little engineering effort as possible. We aim towards an architecture that is fully compliant with U.S. Army-grade verification and validation guidance and robust enough for decision-oriented analysis while maintaining flexibility and quickness in order to save the Army tremendous amounts of time and effort [4] when constructing distributed M&S environments for various uses.

Hands-on Overview

Scope

In reality, the functions that we'll be asking you to do in just a few hours would be done over a long period of time and executed by many people, each with the required skillset. EASE is still a research project and not ready to be used by modeling and simulation projects. We hope to expose enough EASE functionality to you during this workshop in order to solicit feedback so that we may improve EASE. If at any time, you have questions or would like a better explanation of the EASE system, please do not hesitate to ask an EASE team member.

We've provided pre-built materials that would normally take several days, weeks or even months to build depending on the complexity and availability. You will be working through a use case that allows you to work within multiple areas of EASE without having to spend weeks entering an entire system design, compiling and installing many applications or developing scenarios. Please consider these points while working within the tool and ask us for help along the way.

Plan

There will be teams of up to three people stepping through the instructions. We'll attempt to have varying skillsets teamed together in order to cover a wide breadth of simulation users. We encourage members of the team to take turns through the steps so each person executes the part of EASE most relevant to their role in their respective organization.

Plot

Imagine if you will, that in a modeling and simulation program far, far away, that simulation requirements are captured and organized into warfare capabilities that need to be represented. Those capabilities are correlated to technical implementation solutions so the technical team knows which application is representing each part of the capabilities. The technical design is captured down to a level of detail where each exchange of information is defined down to the attribute. The required business logic and valid datum are captured in order to automatically test the implementation based on the system design.

Software is installed one time and the configuration of each application is understood by the computer well enough to automatically execute the simulation environment without the need for non-M&S specialist users to know how to run the often complex software. To really blow your mind, the execution occurs within a cloud environment reducing the program's hardware, network and engineering requirements. Scenarios are assigned to applications and organized for easy access and navigation through a web page for the ultimate simulation execution by a non-M&S specialist users.

Within this alternate universe is the need for three brave simulation professionals. You and your team will teleport into this alternate universe and help the described simulation program update their system. The software developers have delivered a new version of their simulation. It now has new functionality that needs to be accounted for within the larger system design and the software has to be updated within the execution environment. This new capability needs to be included within the scenario description for the M&S users to understand what they're executing. The M&S users will need to get the data collected from the simulation environment for analysis, but they don't know anything about the operating system that the new software uses, nor do they know how to run the complex software along with all the other models and simulations that must run concurrently.

Hands-on Instructions

There are seven phases to the workshop instructions. Each phase represents a function that users would execute using EASE within a typical modeling and simulation environment. Please follow the instructions as written and let a member of the EASE team know if you have any questions. We'll be happy to help clarify or explain any of the steps. We'll also be happy to explain these steps in more detail so you better understand how each step may or may not apply to your organization, role and environment.

Each workstation will be already signed in, but usernames and passwords will be provided at each station in case they are needed. If you encounter any problems along the way, like error messages or a screen that doesn't match the description within the instructions, simply let us know and we'll address the situation by proving to your supervisor that it was your fault, not ours. *That is just a joke (as far as you know)*. Please feel free to talk to one of the EASE team members for questions or issues at any time.

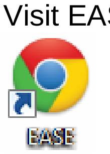
Phase One – Update Information within the System Design Description

Task Description

In the following EASE phase, you will update the system design details in the System Design Description (SDD) based on a software update by the development team. The new version of the software has new functionality that will contribute to the warfare representation and will later be executed within EASE. The new software update now has a configurable heartbeat time for situation awareness messages and it now provides the size of the message as a parameter.

Instructions

For the purpose of accomplishing this task within the allotted time, you are asked to perform the following tasks:

Step	***Instructions***
1	Visit EASE in a browser by double clicking on the **EASE** desktop icon. 
2	Login to the system as the systems engineering username ("seuser") with the password provided at your workstation.
3	Go to the systems engineering actions page by clicking on the **System Design** icon (gears). 
4	The Architecture Version is denoted in the pull down menu near the top of the page. The SDD allows for versioning to properly configuration manage the simulation environment's design. Check to ensure that the Architecture Version is set to "Version 5.0" to update the correct version of the system design.
5	You will be updating the system to include an enhancement to an application, the Situational Awareness Normalization and Dissemination Service (SANDS). This update

	will enhance the capability that is being represented within the system and require a change to the system design. The new version of SANDS has a configurable heartbeat interval value and now publishes an additional attribute, *Size*, in the Situation Report interaction. We'll start with the capability description. Click on the **Functional Views** tab on the left side of the screen. Then click on the **Capabilities** link under that tab.
6	Find the **Blue Situation Awareness Information Sharing** capability and click on the title. Click on the **Edit** tab under the title of the page. Add the following text to the bottom of the description field, "The timing for the frequency of communications between blue platforms is configurable which allows analysis of the communications timing to optimize sharing information across the force structure." Scroll to the bottom of the page and hit the **Save** button.
7	Now you need to update the application's current details. Click on the **SDD** link near the top left of the screen. Click on the **Technical Views** tab on the left side of the screen. Then, click on the **Components** link on the left side and scroll down to find the application, "Situational Awareness Normalization and Dissemination Service – SANDS" which will need to be updated. To the right of the SANDS component row, click on the edit icon: . In the description box, add the text, "The heartbeat interval is configurable." Scroll to the bottom of the page and hit the **Save** button.
8	Now you need to update the design details. Click on the **SDD** link near the top left of the screen. Click on the **Event Sequences** link (under the Technical Views tab) and find the event sequence **Friendly Oriented LOP/COP Reporting and Management**. Click on the title of the event sequence.
9	Click on the pull-down that says **Functional** and change that to **Component**. You should see the name of the application within the title of a swim lane. These are the applications allocated to those M&S Functions.
10	Click on the **Edit** tab under the title of the page.
11	Scroll down to the "Sequence Editor" section of the page. Drag and drop the **Internal Proc** icon (Internal Proc.) onto the top gray block of the center swim lane labeled, "Friendly Oriented Message Creation".
12	Click on the icon next to the new event (*event_7*) at the bottom of the sequence diagram. Select **Move Up** to push the event upwards. Do this step once more on the same event so there are two events below this event.
13	Click on the icon to the left of the new event and select **Edit**. Change the label of the event to "Check Heartbeat Interval" and hit the **Save** button.
14	Scroll to the bottom of the page and hit the **Save** button.
15	Click on the interaction **Outbound SITREP**. This will bring up a page with a view of two functions with a line titled with the interaction type. Click on the label of the interaction within the graphic **SituationReport**.
16	Click on the **Edit** button (Edit) on the right (the button, not the Edit tab under the title of page) in order to toggle the ability to add a new parameter. Check the boxes for Used and Required for the *Size* attribute to denote that the system now provides that attribute. Click on the **Edit** button (Edit) again to toggle out of editing mode. Your changes are saved.
17	Click on the **SDD** link at the top left of the page to return to the SDD. Click on the **Technical Specifications** tab on the left side of the screen. Then click on the **System /**

	Subsystem Specification (SSS) menu item where you will verify your changes within the System / Subsystem Specification in the next few steps.
18	To regenerate the SSS based on the changes you've made, click on the button on the right labeled **(Re)Generate**  . This will take a few minutes. A status bar will show the progress of the generation. The system is querying the database for all events, components allocations and generating "shall statements".
19	Scroll down to the application, Situational Awareness Normalization and Dissemination Service (SANDS), to find the event that you've updated, **Situational Awareness Normalization and Dissemination Service - SANDS shall send the Interaction Situation Report**. It is formed to look like "<model name> shall <send OR receive> the <Interaction OR Object> <name of interaction>". Click on the specification link in the right column.
20	Verify that your attribute change (the used and required flags) has been included in the SSS statement. Verify that *Size* checkmarks are correct (both "Yes").
21	Logout of EASE by clicking the **Logout** link at the top right corner of the page and close the browser window. Now is a good time to switch the person who performs the actions.

Comments

Please provide feedback on the software that you used in this phase:

Phase Two - System Design Description – Test Cases and Surrogates

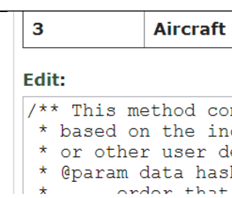
Task Description

In the following EASE phase, you will allocate technical solutions and information exchange definitions to the functional design you entered in phase one.

Instructions

For the purpose of accomplishing this task within the allotted time, you are asked to perform the following tasks:

Step	***Instructions***
1	Visit EASE in a browser by double clicking on the EASE desktop icon.
2	Login to the system as the systems engineering username ("seuser") with the password provided at your workstation.
3	Go to the systems engineering actions page by clicking on the **System Design** icon (gears). 
4	You will be updating the test case for SANDS to include the system design enhancement you made in the previous phase. This update will allow developers to test the capability that was updated in the system design.

	Click on the **Testing & Surrogates** tab on the left side of the screen. Then click on the **Test Case Generator (ATC)** menu item. Click on the **Test Cases** tab at the top of the screen.
5	Click on **Friendly Oriented LOP/COP Management** in the “Test Cases” column of the table (fifth one in the list).
6	This page displays the sequence diagram, the flags for the test (Tolerate Extra Events and Continue After Fail), the swim lanes and the events that can be tested.
7	At the bottom, under the “Test Sets” label, click on the title of the test set **Friendly Oriented LOP/COP Management TS**.
8	Click on the **Outbound SITREP** event link at the bottom left of the sequence diagram. This will insert the event’s details below the sequence.
9	Click on the **Edit Event** icon , which is under the sequence diagram. It has a pencil within the icon.
10	Click on the icon () to the left of *Size* to add a test value. This will bring up a line allowing you to set the validation criteria for this attribute of the event. Click on the checkbox **For Validation**. Select **Range** in the first pull-down, **EqualTo** in the second pull-down and enter the values “1024” and “1048576” in the two input fields. This updates the test set to ensure that this parameter is within the allowed range of values. This is a good way of providing a first level of testing for developers.
11	Save these updates by clicking on the **Edit Event** icon  (with the pencil) that you clicked before under the sequence diagram. Hit the **Commit** button. Verify that *Size* now has the validation line that includes “==1024…1048576”.
12	Return to the ATC page by clicking on the **ATC** link at the top of the screen.
13	Click on the **Surrogates** menu item within the “Testing & Surrogates” tab on the left side of the screen. Then click on the **Surrogate – Blue SA Responder** surrogate link.
14	Click on the **Edit** tab under the title of the page.
15	Scroll down to the <u>Script</u> section and click on the **Edit:** link. This will pop-up a download dialog in the browser window. Click on the **Keep** button. When the download is done (it stops flashing), click on the filename of the download to open the file. This will start a Java WebStart application and add a Java program icon to the Windows task bar. Click on that icon to bring up the application to the foreground. Maximize this window. 
16	In the middle of the window, click on the **Show Test >>** button.
17	Click in the editor window on line 11 to get your cursor set. This tells the application where to insert the statements you’ll walk through in the next few steps.
18	Change the <u>Event</u> pull-down at the top right of the window to **2 – BlueSAResponse [O]**. Click on the line **(array)+Communication.Receiver** to highlight the line and then click the **Add** button at the bottom of the window to add an element under that array item you had highlighted.
19	Double-click on the black text portion of the new element **(String)[0]** under the “Communication.Receiver” line. This will add that variable to the editor where your cursor was placed.
20	Move the cursor to the end of that line and type “ = “ so you can assign that variable to the next element.
21	Change the <u>Event</u> pull-down in the editor window to **1 - BlueSARequest[I]**. Double-click on the black text of the line **(String)Communication.Originator**. This will make the response message’s recipient equal to the requestor’s name. This sends the response

	to the platform that made the request in the simulation.
22	Click the **Execute Script** button at the bottom-right of the window. Click the **Apply** button in the middle of the window. Click the **Close** button next to the "Apply" button.
23	Changes will not appear in the browser yet due to the technical nature of Java Webstart and the browser. Scroll down and hit the **Save** button. Click the **Edit** tab under the page title. Scroll down to the "Script" section to see and verify the changes you made in the editor.
24	Congratulations! You're done acting as the systems engineer. Please **Logout** and close the browser and think about what you should buy this weekend to celebrate while your team switches who performs the steps on the computer.

Comments

Please provide feedback on the software that you used in this phase:

Phase Three – Export Test Case and Surrogate

Task Description

In the following EASE phase, you will export the test case and surrogate from EASE in order to provide to the development team prior to integration.

Instructions

For the purpose of accomplishing this task within the allotted time, you are asked to perform the following tasks:

Step	***Instructions***
1	Visit EASE in a browser by double clicking on the **EASE** desktop icon.
2	Login to the system as the integrator username ("intuser") with the password provided at your workstation.
3	Click on the System Design icon. 
4	Click on the **Testing & Surrogates** tab on the left side of the screen. Then click on the **Test Case Generator (ATC)** menu item.
5	Click on the **Export** tab near the top of the screen.
6	For the "Test Case" pull-down, select **Friendly Oriented LOP/COP Management** and click the **Next** button. 
7	For the "Test Set" pull-down, select **Friendly Oriented LOP/COP Management TS**. Do not select a precondition and click the **Next** button.
8	Name the test "Friendly SA Test" and enter "FriendlySA" in the filename field. For the "Schema version" pull-down, select **1.3** and click the **Next** button.

9	Verify the information and click the **Export** button in the middle of the screen. Your test will be added to the “Existing Files” section at the bottom of the page.
10	Click on the **Download** icon on the right side. This will initiate a download in the browser. Click on the filename of the download when it stops flashing. This is the test case in XML format. This file can be imported into the Advanced Testing Capability (ATC) tool and used to test software over the simulation middleware. Close the XML file and return to the browser.
11	Click on the **Surrogates** menu item under the “Testing & Surrogates” tab on the left side of the screen.
12	Look for the icons on the right side of the screen under the Export column.
13	Click on the left-most icon in the row for the “Surrogate – Blue SA Responder” row to download the Test Case Markup Language (TCML) file which can be loaded and executed by the Advanced Testing Capability (ATC) tool for testing of simulation systems.
14	Select **Blue SA Request** in the pull down and click the **Next** button.
15	Name the file “BlueSASurrogate” and click the **Generate** button.
16	At the bottom of the browser window, you should see a download pop-up with the file listed. Click on the filename of the download when it is done flashing to open the file. This is the TCML file for the generated surrogate, which can be loaded in the ATC tool. Close the XML file and return to the browser.
17	Click the **SDD** link at the top of the browser page to return to the front page of the SDD.
18	Click on the middle icon on the “Surrogate – Blue SA Responder” line to download a surrogate which can be run as necessary. Select **Blue SA Request** in the pull-down and click the **Next** button. Then fill in the Federate Name with “BlueSAFederate” and the Destination Directory as “C:\tmp”. Click the **Generate Federate** button to download the federate.
19	Click the **Keep** button on the download button and then click on the filename of the download once it has stopped flashing (downloading). This will launch a Java WebStart application to install the federate in the specified directory, “C:\tmp”. This will take a minute.
20	It will pop-up a window saying that your code has been generated and placed in C:\tmp. Click on the **Yes** button to see the HTML Test Procedure. This test procedure is meant for testers to document results. Close this browser tab by hitting *Ctrl-W* on the keyboard and open a Windows File Explorer (Windows key and E at the same time). Navigate to C:\tmp to see the federate directory. Open that directory. The directory has documentation (\docs) with the test procedure, required software libraries (\lib), source code (\src) and a build file to compile the source code into an executable federate. To see the generated Java code, look in the \src\mil\army\matrex\atc\fed\ directory for the Java file. Feel free to open that Java file to see the generated source code. Close the Windows File Explorer and return to the browser.
21	Click the **SDD** link at the top of the browser page.
22	Click on the right-most Deploy icon on the “Surrogate – Blue SA Responder” line to deploy the surrogate to the EASE deployment system for future execution with EASE.
23	Choose **Blue SA Request** in the “Blue SA Request / Response” pull-down and click the **Next** button.

24	Enter a federate name “Blue SA Surrogate” and click the **Deploy** button. This will send the surrogate to the EASE cloud for future use.
25	**Logout** of EASE and close the browser. This is another great time to switch team members.

Comments

Please provide feedback on the software that you used in this phase:

Phase Four - Deploy Asset Management – Install Software

Task Description

In the following EASE phase, you will install software in EASE.

Instructions

For the purpose of accomplishing this task within the allotted time, you are asked to perform the following tasks:

Step	***Instructions***
1	Now it is time to upload the updated version of the SANDS software.
2	Visit EASE in a browser by double clicking on the **EASE** desktop icon.
3	Login to the system as “intuser” using the password provided at your workstation.
4	Click on the Developer person icon to upload and configure software. 
5	Insert the CD labeled as SANDS 4.3.0 at your workstation into the computer.
6	Type the following values into the form fields. Name: “SANDS MTX” Description: “Situational Awareness Normalization and Dissemination Service (SANDS)” Set field pull downs to the values below: Hardware Requirements: **Linux – Big Instance** Version: “4.3.0” Select the Cooperation this application will join: **MATREX HLA** Select the Trap that will collect data from this application: **OneSAF AAR + HLA Results**. Click the **Next** button at the bottom of the screen.
7	Bring up a file explorer window by hitting the Windows key and the letter ‘e’ on the keyboard at the same time. Navigate to the **DVD RW Drive (D:) SANDS MTX** under the “Computer” section. Position the file explorer so you can see both the files list and the EASE window with the **Drop Area** box appearing.

	Drag the zip file named, “SANDS.zip” onto the browser in the **Drop Area**. This examines the zip file containing the updated software for plain text files that may be considered configuration files that the developer would like to edit for EASE execution. Click the **Next** button at the bottom of the screen.
8	Click on the **msggencrit.xml** file (this filename is listed in the fourth green box). This opens the configuration file in the editor below. On line 11, highlight the value **1200000** without highlighting the quotes around it. Then click on the **Add Custom Property**. This will pop up a box. Fill in the fields as listed below: Name: “heartbeatInterval” Type: **integer** Value: “1200000” Notes: “Time interval to send SituationReport heartbeats” Click **Save**. The property you just set should appear in the table at the top of the screen next to msggencrit.xml. In the editor, on line 11, you should be able to see a change of the 1200000 value to be the variable name (${heartbeatInterval}) that EASE will use to configure SANDS based on the M&S user’s input through the EASE interview. Scroll down and click **Submit** at the bottom of the screen to have the software sent to the cloud.
9	This launches a virtual machine set that installs the software you just uploaded and executes it for you to verify that it was done correctly. Login using the developer virtual machine credentials provided at your workstation. This may take a few minutes. The browser window will show a virtual machine. You can ignore the buttons at the top of the browser window. Those are to help the user interact with the virtual machine if necessary.
10	 Double click on the **Test Configuration** icon to launch the software you just uploaded. The correct cooperation, which is any software that should be running prior to this component running, is already executing: the RunTime Infrastructure (RTI). You will see a terminal open with the SANDS console.
11	 Double click on the **View RTI Exec** icon to open the RTI viewing terminal. Within the RTI window you should see SANDS join the federation. Look for the text, *Federate SANDS_RN9_23 (handle = 1, nodeID = 1) is JOINING federation MATREXPEO …* This interface allows the developer to interact with their running application to ensure it was uploaded, installed and configured correctly. Click on the SANDS terminal to get focus on the SANDS prompt, *SANDS_RN9_23* >. Type “help” to see that developers can interact with the software.
12	Congratulations! You’re done acting as the integration / developer engineer. Close the browser and pat yourself on the back.

Comments

Please provide feedback on the software that you used in this phase:

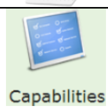
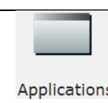
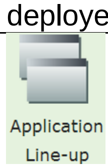
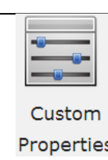
Phase Five - Interview Interface – Link Design to Execution

Task Description

In the following EASE phase, you will create the connection between the system design you created in phases one and two with the software and configuration elements you created in phases three and four.

Instructions

For the purpose of accomplishing this task within the allotted time, you are asked to perform the following tasks:

Step	***Instructions***
1	Go to EASE Interview by double-clicking on the **EASE** icon on the desktop. Click on the Systems Engineering Person icon. 
2	 Click on the **Capabilities** link in the Systems Engineering User section. Verify that the Capability that you just updated (Blue Situational Awareness Information Sharing) appears in the list with the updated text, *The timing for the frequency…*
3	Return to the **Available Actions** page (link near the top of the screen) and click on the **Applications** link in the Systems Engineering User section. Scroll down until you find the application *Situational Awareness Normalization and Dissemination Service - SANDS* and verify that the SANDS MTX mode is “Installed”. You can also search for the surrogate (Surrogate – Blue SA Responder) that you deployed in phase 3. 
4	 Return to the **Available Actions** page and click on the **Application Lineup** link in the Integrator User section. There are many lineups so it will take a few minutes to fill in the right side of the screen, but you don’t have to wait. On the left side of the screen, click on the **Approved** checkbox under the *Approval* section to reduce the lineups shown. Examine the application lineup details and verify that *SANDS MTX* appears in the approved lineup, *BMCS Plus OneSAF MTX*.
5	Return to the Available Actions page and click on the **Custom Properties** link in the Systems Engineering User section. Find the application that you created custom properties for in phase four, Situational Awareness Normalization and Dissemination Service - SANDS. Click on the mode you updated in phase four, **SANDS MTX**. 
6	In the bottom table labeled *Advanced Properties:*, you will see the heartbeatInterval property as an integer. To wrap this property to allow a non-M&S specialist to select appropriate values, click on the **New Wrapper** button. In the name field, type “Situation Report Heartbeat”. Type “The heartbeat interval time for Situation Reports” in the

	description field. Select **heartbeatInterval** in the Advanced Properties pull-down. Choose **Enumeration** for the Type. The Group field is name of the section that will appear on the execution page so type in “Blue SA”. Choose **Blue Situation Awareness Information Sharing** for the Capability pull-down field.
7	Click on the **Edit…** button. Type “Quick” in the Name field (the non-M&S specialist users’ view) and “Frequent updates” in the Description field (the tool-tip for the non-M&S specialist users). Click on the orange number **1200000** and type in “600000”. Click the **Add** button to save this as an option. You’re going to add two more by changing the fields in place. Change the name, description and values fields to: Name: “Standard” Description: “Current force intervals” Values: 1200000 Click the **Add** button. Last one: Change the name, description and values fields to: Name: “Long” Description: “Less updates / communications” Values: 3600000 Click the **Add** button. Click to the **Ok** button to save these choices. Hit the **Save** button.
8	 Return to the **Available Actions** page and click on the **Scenario** link in the Scenario Actions section. Verify that for the *Medium Civilian Population Scenario* that *Situational Awareness Normalization and Dissemination Service – SANDS (SANDS MTX) - SANDS Default Scenario* appears under the list of Applications.
9	Return to the **Available Actions** page and click on the **Execution Search** link in the Modeling and Simulation User section. On the left side, under the *Capabilities* section, verify that the capability description is updated by clicking on the information icon ⓘ next to the capability title, *Blue Situation Awareness Information Sharing*. Look for the paragraph you added, “The timing for the frequency of communication, etc.” Scroll down and click on the execution, **Medium Civilian Population Scenario** execution. 
10	Verify that the capability, *Blue Situation Awareness Information Sharing* is listed in the Capabilities section. Click on the **Advanced** link in the right side of the Capabilities section to verify that the application, *SANDS MTX* also appears.
11	**Logout** out and close the browser. You’re done with this phase of the workshop.

Comments

Please provide feedback on the software that you used in this phase:

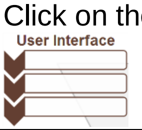
Phase Six - Interview Interface – Execute Simulation

Task Description

In the following EASE phase, you will find and execute the simulation environment that you have managed in the previous steps. Remember to get excited about hitting the Go button!

Instructions

For the purpose of accomplishing this task within the allotted time, you are asked to perform the following tasks:

Step	***Instructions***
1	Go to the EASE page by double-clicking on the **EASE** icon on the desktop.
2	Login to the system as “msuser” using the password provided at your workstation.
3	Click on the **User Interface** button. 
4	You want to execute a scenario with a small amount of entities so under the “Platforms” section on the left side, check the **1-200**, **201-300** and **301-1,000** checkboxes. Notice that as you click on the checkboxes, the matching executions change on the right-hand side of the screen. Find the execution, **Medium Civilian Population Scenario** that you verified in the previous phase and click on its title.
5	In the “Capabilities” section, click on the **Advanced** link on the right to ensure that SANDS MTX appears as an application to be executed.
6	Click on the **Blue Situation Awareness Information Sharing** section. Open the pull-down field to see the choices you created for the user in phase five. Mouseover the blue question mark icon next to the pull-down to see the description you entered. Select one of the choices and then click on the **Advanced** section right below the pull-down. At the bottom of the list, you’ll see the custom property **heartbeatInterval** which the user can change to a value of their choice. Change the heartbeat interval configuration to 900000
7	Select **All** for the data collection selection.
8	Set the name and description fields to something you can identify when you return after lunch.
9	 Press the **Go** button. This will launch the simulation environment in the cloud using virtual machines.
10	The system will show you a screen with a green running icon on the top right.  Scroll towards the bottom of the page to monitor a video stream of one of the virtual machines executing. An M&S user could watch the stream to verify that the system is running, watch to ensure the right events are occurring and in the future, even interact with the virtual machines during the run. OneSAF will launch after a few minutes.
11	Wait to see OneSAF start and then **Logout** and close the browser.
12	Have a well-deserved break for lunch while your execution completes. Give somebody on the EASE team a high five for being such an awesome EASE user.

Comments

Please provide feedback on the software that you used in this phase:

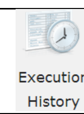
Phase Seven - Interview Interface – Examine Simulation Data

Task Description

In the following EASE phase, you will validate that EASE returns data that an analyst would use. EASE automatically generates PowerPoint from the OneSAF AAR tool to make the visualization of the data easy for the M&S user.

Instructions

For the purpose of accomplishing this task within the allotted time, you are asked to perform the following tasks:

Step	***Instructions***
1	Go to the EASE page by double-clicking on the **EASE** icon on the desktop.
2	Login to the system as “msuser” using the password provided at your workstation.
3	Click on the **M&S User** person button. 
4	Click on the **Execution History** link in the “Modeling and Simulation User” section. 
5	Find the run that you executed in the previous phases and click on the title of your execution.
6	 Click on **HLA Results All** artifact (HLAResults is a COTS tool that collects data over the middleware). This will download a zip file of the collected data from your execution run. Open the zip file (by clicking on the filename of the download) and verify that there is a MySQL file. This file contains the database dump from the execution database. Note the size of this file for the next step in this phase. Open the .mysql file (double click on the filename) in Wordpad to see the database dump commands exported from MySQL. The user could import these files into a local instance of MySQL in order to operate their own data analysis tools, queries or views.
7	Click on **HLA Results Critical** artifact. This will download a zip file of only the critical data (as defined by the system design of the capabilities you selected) from the execution run. Open the zip file and verify that the file size is much smaller than the file from the previous step.
8	Click on **OneSAF_AAR** database link. This will download a zip file of the data that OneSAF collected during the run. This data is different since OneSAF logs more data than it sends over the middleware to be collected by HLA Results. Additionally, OneSAF doesn’t subscribe to everything that is sent over the middleware in order to log it. Open the zip file and verify that there is a PostgreSQL file.
9	Click on **OneSAF_AAR** slides. This will download a PowerPoint file that will open in a simple viewer. The first slide is all white so once the mouse icon gets back to normal (it

	is done downloading) you can scroll down with the mouse wheel or click on the right arrow button at the bottom right of the window. This is an automated artifact that normally humans would have to generate using the OneSAF AAR tool. EASE has scripted the necessary GUI button clicks in order to do this in an automated manner.
10	Congratulations! You’re done. Please close the browser, close your eyes and imagine that you’re in your favorite vacation destination with all of your loved ones. For some thought provoking examples of our favorite vacation destinations, please refer to Appendix B.

Comments

Please provide feedback on the software that you used in this phase:

APPENDIX L: CONSENT AGREEMENT

University of Central Florida

EXPLANATION OF RESEARCH

Title of Project: Limitations of Micro and Macro Solutions to the Simulation Interoperability Challenge: An EASE Case Study

Principal Investigator: *John M. Barry*

Faculty Supervisor: *Dr. Michal D. Proctor*

You are being invited to take part in a research study. Whether you take part is up to you.

- *The purpose of this research is to evaluate and provide and overall assessment of the EASE prototype as a potential M&S tool for the U.S. Army to help mitigate the challenges of interoperability*
- *Each participant is asked to take part in answering a one-page questionnaires.*
- *It is expected to take approximately 20 minutes to complete the questionnaire.*

You must be 18 years of age or older to take part in this research study.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints *John M. Barry, Graduate Student, Modeling and Simulation Program, College of Inter Disciplinary Studies, (407) 601-0083 or Dr. Michael D. Proctor, Faculty Supervisor, Department of Engineering (407) 823-5296 or by email at michael.proctor@ucf.edu.*

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901.

APPENDIX M: IRB APPROVAL

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **John M. Barry**

Date: **October 02, 2012**

Dear Researcher:

On 10/2/2012, the IRB approved the following activity as human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Project Title:	Limitations of Micro and Macro Solutions to the Simulation Interoperability Challenge: An EASE Case Study
Investigator:	John M. Barry
IRB Number:	SBE-12-08655
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Patria Davis on 10/02/2012 02:55:44 PM EDT

IRB Coordinator

APPENDIX N: CONSOLIDATED DATA OF THE PARTICIPANTS' RESPONSES TO QUESTIONS 1-26 OF THE POST EASE HANDS-ON SURVEY QUESTIONNAIRE

Domain	*UC	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q24	Q13	Q14	Q15	Q16	Q17	Q18	Q22	Q25	Q19	Q20	Q21	Q23	Q26
TEMO	1	6	7	6	6	6	6	7	5	4	4	5	4	5	4	5	5	5	3	4	4	6	5	5	5	5	6
TEMO	2	5	6	6	7	7	7	6	6	7	6	6	5	6	6	5	3	6	6	5	2	5	6	6	7	6	6
TEMO	4	7	7	6	7	7	7	5	6	6	6	6	7	6	6	6	7	5	4	4	4	5	6	5	6	4	5
TEMO	4	7	7	7	6	6	6	5	7	5	5	5	4	6	5	6	6	5	7	6	3	5	6	6	6	4	6
RDA	1	7	4	6	6	6	6	5	5	3	5	5	4	6	4	5	6	5	5	5	4	6	5	4	5	4	5
RDA	1	7	4	7	7	7	7	7	5	6	6	6	4	6	6	4	3	5	6	5	2	5	5	6	6	6	6
RDA	4	3	3	3	4	4	6	5	4	5	5	4	5	4	6	4	3	4	6	4	4	4	4	4	4	4	4
ACR	4	7	7	6	4	5	6	5	3	4	4	5	5	6	6	6	6	6	3	6	3	5	6	6	3	5	5
ACR	4	4	7	2	7	6	4	4	4	4	4	5	4	4	4	7	4	4	4	4	1	4	4	4	4	3	4
ACR	4	7	7	7	7	7	7	2	6	6	3	2	3	5	5	6	7	7	4	4	6	5	4	4	5	5	5
ACR	3	7	7	4	4	5	5	5	4	5	4	3	3	6	3	4	5	5	5	5	4	6	4	4	5	4	5
		67	66	60	65	66	67	56	55	55	52	52	48	60	55	58	55	57	53	52	37	56	55	54	56	50	57

APPENDIX O: CONSOLIDATED PARTICIPANTS' RESPONSES TO FREE RESPONSE QUESTIONS 26-30

Question 26

Domain	UC	Q#	Free Response
ACR	4	26	As a program of record, M&S developers would need to populate the SDD/SE data IOT facilitate the user's execution. This in itself would have long standing intrinsic value to the entire community. If so (developers populate the baseline SDD info) then adding/updating would be feasible. having the level of SE data would certainly assist in the interoperability testing and V&V.
ACR	4	26	Biggest benefit of a tool like EASE is to remove the interoperability challenges across the M&S Enterprise. An organization that develops, maintains, and uses its own models can benefit by leveraging other models in the community tat perform a function that our own models don't do will or at all. Our developers gain experience and train the junior analysts / modelers. We depend on maintaining that institutional knowledge to keep our models relevant and functional to meet the dynamic needs of our organization.
ACR	3,4	26	As an immature solution, EASE shows a lot of potential. Aspects of EASE such as the SDD can be used almost immediately and can provide a forward lean to populating a production system
TEMO	1	26	Since training is limited not all systems truly have an expert managing them. So if the systems were pre-configured within EASE then it would eliminate some of the overhead involved in configuring the interoperability piece.
TEMO	4	26	Interoperability challenges can be reduced by having the ability to use previously used scenarios edited for other training events.
TEMO	4, 5	26	Just identifying the mappings is key. "x" has this attribute and interactions while "y" has these attribute and interactions then could allow one to quickly to integrate or identify the sort falls.
TEMO	1, 2, 4	26	Seems like most interoperability challenges can be rectified via the EASE user interface and do not require a programmer
RDA	1	26	By allowing execution after a virtual set-up, EASE will make it much easier for engineers to comprehend and reason about interoperability, and to install solutions that address requirements
RDA	4	26	My organization would need to describe the information/data flow for completing a study/analysis; identify the tools used and the data inputs required/output produced; and indentify the linkage between amjor analytic objectives and feeders of data / analysis to those objectives. Then could trun this schematic over to EASE developers and see if they could produce the EASE "version" that would support our need - with emphasis on accuracy of the work, cost savings in both time and labor, and allowing rapid turns and database structures for storage of sensitibity cases ans system alternatives excursions. If my organization can see these benefits, they wouldbe much more likely to participate in the effort to develop EASE further.
TEMO	1, 4	26	Depends on the amount of info available at the front end of EASE and who is responsible for making sure that info is available to the community. And there are significant back end challenges related to software installation and configuration that could make that part of EASE less valuable. All of the above is likely magnified in a joint environment as well.

Question 27

Domain	UC	Q#	Free Response
ACR	4	27	If I can run my organization's models and leverage other models to perform other functions, that would be most beneficial. Also, having a consistent post-processor that works across models would be helpful.
ACR	3,4	27	Creation and maintenance of the SDD
TEMO	1	27	Being able to launch multiple applications from one central management system
TEMO	4	27	The scenario interview and AAR tools are most beneficial
TEMO	1, 2, 4	27	Integration of the architecture to support the objectives of the simulation is huge. Focusing on the capabilities required for a sim and linking the platforms to the capabilities is clearly where the focus needs to be in my mind. The ability to run test cases allows us to isolate a new development to identify only what needs to be fixed and eliminate a lot of unnecessary trouble shooting. On the department side - the surrogate concept is brilliant in that it allows continued development of new capabilities with out shutting down current work
RDA	1	27	Automated test case generation and defined lineups of candidate solutions

Question 28

Domain	UC	Q#	Free Response
ACR	3,4	28	1) Architecture development is still a major gap that is executed by all organizations at some level. Integrating development tasks that assist in system views production would seem a natural extension to EASE. 2) VM integration is 1/2 of the deployment problem. Most users will also need physical deployment tools. EASE should address both issues. 3) Mission Command systems are the last piece to the problem set that doesn't seem to be addressed in EASE yet.
ACR	4	28	Archiving modeling results into a repository that can be used without rerunning the models would be helpful. Literature Review.
TEMO	1	28	The ability to access a library of simulations instead of it being limited to only the sites applications
TEMO	4	28	Add voice capture to AAR to allow conversations between TOCs (Staff) and lower echelons to be replayed along with video (FM Comms)
RDA	1	28	Engineering data collections during execution. Always on displays of context. We know where we are in the tool at home. Whenever solutions are displayed, provide for a lot of on-line help. Mouse over help for each feature or module. Graphically represent phase VI that call's the user's attention to the buttons or gages them. Add multiple ways to get to the specific functionality desired...for instance, get to execution history by user interface on cloud execution
ACR	3,4	28	The ability to maintain a set of entities along with their enumerations to automate mapping file creation.

Question 29

Domain	UC	Q#	Free Response
	4	29	Making sure that all data is consistent across all models is a challenge. Ensuring functionality and effects are consistent is also challenging
ACR	3,4	29	Transport architecture (RTI) configuration for cross-simulation data exchange. For example, in a hybrid architecture (HLA & DIS) entities must be mapped differently in both model sets
TEMO	1	29	Knowledge and skillset
TEMO	4	29	The interoperability of logistics (JDLM) is the main simulations challenge in my organization
TEMO	1, 4	29	HLA-->DIS DIS-->HLA interoperability
RDA	1	29	Semantic differences between similar (but not same) applications.

Question 30

Domain	UC	Q#	Free Response
ACR	4	30	Other then the SE interoperability; there still exists terrain and performance data gaps that require tedious testing and trial / error discovery. A tool which addresses this issures would be greatly useful in identifying problems before execution and allow fixes or work-arounds ahead of time.

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