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THE MODELING ARCHITECTURE FOR TECHNOLOGY, RESEARCH, AND EXPERIMENTATION

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ABSTRACT

The Modeling Architecture for Technology, Research, and eXperimentation (MATREX) program is the foremost distributed modeling and simulation environment in the US Army, providing a unifying M&S architecture, supporting tools, and infrastructure to ease the integration and use of multi-resolution live, virtual, and constructive (LVC) applications. We present the MATREX program overview and objectives, describe the current state of the architecture, tools, and services, and discuss near-term developmental efforts. We then briefly address two applications of the MATREX environment, namely the application in the Future Combat System Lead Systems Integrator System of System Integration Laboratory, and the Cross Command Collaboration Effort. Finally, we describe the lessons learned in the process, describing the obstacles encountered and the mitigation techniques employed, as well as the program successes.

1 INTRODUCTION

"What is the Matrix?" is the key question asked by Neo in the 1999 hit Warner Brother's movie. In the movie "The Matrix," the answer unfolds as the story progresses. While Morpheus tells Neo that the Matrix is a "neural interactive simulation," he concedes that the answer is unsatisfactory, and that in order to really understand the nature of the Matrix, you have to see it for yourself. We aim to answer the question, "What is the MATREX?" for the reader, and offer an invitation to journey with us down the rabbit hole.

2 RATIONALE

The US Army continues its Herculean effort to transform itself from a cold-war era heavy-armor based, pre-positioned force into a lighter, more deployable, lethal, and survivable force that is agile enough to adapt to a wide spectrum of conflict. In order to do so, the Army continues to rely heavily on the simulation disciplines to address operational effectiveness of proposed materiel solutions, and on mathematical modeling to aid in the design of complex systems. Historically, these pursuits have remained separate and distinct, with each giving a cursory nod to the other. When the defense community began experimenting with real-time man-in-the-loop interoperable simulations, the application of these techniques was immediately apparent to the training domain, but less so to the research and development arena. When a class of applications emerged to make the force effectiveness simulations interoperable, the Army began pursuing a campaign of experimentation to employ these to iterate on the organizational design of our forces, and the concomitant doctrine and tactics.

The scientists and engineers engaged in the hard-core process of detailed technical design and analysis determined that these efforts were insufficient to support the highly complex work of weapon system research and development. Their reasons for doing so varied widely, including arguments for greater precision and control, claiming that none of these extant tools, techniques, or procedures were worthy of real consideration for "engineering-level" work. In the mid 1990's, the Department of Defense introduced the High Level Architecture (USD(A&T) 1996), providing a framework to federate dissimilar models and simulations, without artificial temporal or spatial constraints. Several research & development organizations then developed prototype federations to validate the HLA approach, including addressing the concerns of the research and development community. Tracing its lineage back to two of these prototype federations (Briggs 2002, Harkrider 2002, Bentley 2002, McKelvy 2000), the Modeling Architecture for Technology, Research, and eXperimentation (MATREX) now presents a unified Army federation for enabling true engineering-based distributed simulation.

The Army began the MATREX effort in 2003 as a Science and Technology Objective (STO) with a stated goal of designing a simulation architecture and developing a reference implementation that would represent the key characteristics of network enabled battle command warfighting systems. The STO sought to provide a secure persistent environment to support the evaluation of the concepts and technologies associated with the Army transformation. Operating in either a platform-level mode scalable up to a Unit of Action Brigade Combat Team, or in a mode focused on an engineering-level slice/subset, the MATREX environment sought to address deficiencies in domain-specific, stovepiped, and insufficiently interoperable and reusable Department of Defense simulations. Separate from the environment, the MATREX effort was also chartered to encapsulate the entire range of system and technical expertise within the US Army Research Development and Engineering Command (RDECOM).

The RDECOM is comprised of nine distinct mission-oriented research and development laboratories, activities, and centers. These organizations employ very specific and highly detailed physics based models for all of the individual systems and capabilities being analyzed for acquisition. However, the Army transformation is relying heavily on net-centric concepts, where the total utility is much greater than the sum of the parts, and these effects can only be observed in the large. Traditionally, the broader the scope of the problem, the more the community has relied on aggregate level stochastic combat effectiveness models, as indicated in Figure 1.

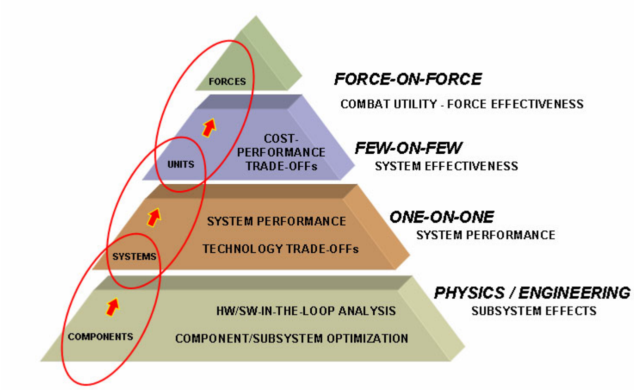

Figure 1: Bottom Up Simulation Hierarchy

This description is somewhat counter-intuitive, as the comparatively small 'cap' of the pyramid is meant to convey the broadest scope, and the 'high' fidelity representations are on the 'low' end of the pyramid. This model does however does suggest that something is lost as you ascend the pyramid. The tradeoff between fidelity and scale has vexed simulationists, who aim to apply the right model to the right problem. Determining if a system model representation is correct in a appropriate operational context remains a difficult practice (Sanders 2006). A preferred approach would retain the physics based models and apply them at the broader scales, as suggested in Figure 2.

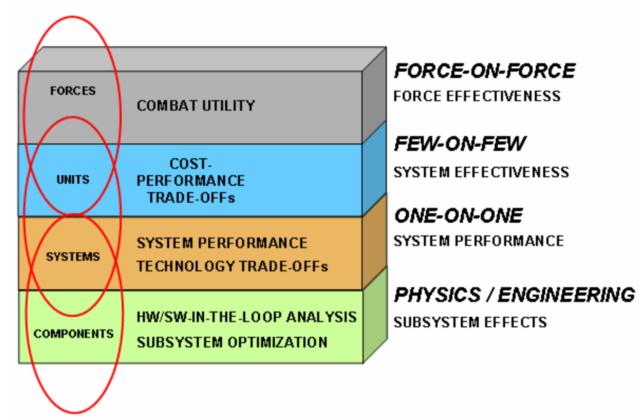

Figure 2: Scale Independent Model

This approach has been historically dismissed as untenable, primarily because of finite computational resources, but also because the problem complexities do not scale linearly with platform/entity/object count. While it may never be possible to explicitly account for every transistor in an entire brigade, the MATREX effort, by utilizing the engineering level models and expertise throughout RDECOM, seeks to push the envelope 'up the pyramid'. Restated, the MATREX enables the federation of these mission-specific 'best of breed' models and simulations into an Army-wide virtual environment suitable to address the specific needs of the research, development, and acquisition domain.

3 APPROACH

The MATREX is first and foremost a service based architecture, providing a computer based synthetic environment in which services exchange object data through a run time infrastructure. It consists of three distinct tiers: a core architecture, the components and tools that are federated upon that architecture, and the persistent infrastructure required to bring them all together into a single execution space.

3.1 Core Architecture

Within the core architecture of the MATREX are three distinct capabilities. The first of these is the run time infrastructure, or RTI, which provides the services described by the High Level Architecture 1.3NG interface specification. The second is the MATREX Federation Object Model, which specifies the objects, interactions, and associated attributes and parameters necessary to reflect all persistent and transient data in the federation execution. Last is the MATREX Middleware Independent Capability (MMIC), an application programming interface that is tightly coupled with the FOM, and aids in the rapid development of MATREX-compatible federates in a data-transport agnostic manner. The current MMIC supports both the High Level Architecture 1.3NG specification, and the Test Enabled Network Architecture (TENA). The MATREX program is also pursuing a developmental effort to provide IEEE 1516 capability with the MMIC.

3.2 Components and Tools

As discussed previously, part of the rationale for building the MATREX is to create a 'best of breed' environment of the various physics-based models and simulations employed throughout the Army's research and development laboratories. These models and simulations, referred to as 'components' in the MATREX, represent a tremendous amount of knowledge capital, and have been developed, validated, and employed in support of various Army acquisition programs. For the 2.0 release of the MATREX, more than twenty of these engineering level components have been integrated into the MATREX Reference Implementation, as depicted in Figure 3. These components cover a broad spectrum from battle command, survivability, communications, vehicle dynamics, sensors, ordnance, logistics, damage effects, to human performance. Accompanying the components are various tools provided by the MATREX program to assist in the integration effort, including an Automated Testing Capability for automated regression testing of updated services. In the 2.0 release of the MATREX, the Objective One Semi-Automated Forces (OneSAF) Testbed Baseline (OTB) provides the platform-level representation necessary to augment the physics-based models.

3.3 Infrastructure

The laboratories, activities, and centers of RDECOM are geographically dispersed throughout the continental United States, so the MATREX program made provision for a persistent distributed simulation development, test, and execution environment through the Distributed Virtual Laboratory (DVL), a secure wide area network that provides data transport services at the Secret level for participating organizations. In addition, the program identified a critical need for an automated and repeatable simulation initialization process (Prochnow 2005), and has made provision for such a process in the MATREX SimInit effort. Finally, in order for the MATREX to support the research, development, and acquisition community, the program is making provision for a federation-wide data collection and analysis effort, identifying the pre-execution, run-time, and post-execution data element collection requirements.

4 APPLICATION

The MATREX effort achieved two program milestones in 2005 when it released the initial instance of the core architecture and selected components to the US Army Future Combat Systems Lead System Integrator (FCS LSI) and to the US Army Cross Command Collaboration Effort (3CE). These events were significant to the program, as they both yielded key insights into the program status and application domain.

In the case of the FCS LSI, the MATREX was delivered as a complete turn-key Government Furnished Equipment (GFX) package, including the RTI, the FOM, and several key services. While the overall effort with the LSI focuses on the integration & test activities, the specific nature of the support has evolved as the effort progressed, and the delivered capabilities were employed a la carte. The LSI needed the MATREX to augment its Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) System of Systems Integration Laboratory (SoSIL) with a few key pieces, instead of the entire battlespace representation. This led to a series of challenges for both the MATREX program and for the FCS LSI, as each had to adjust its respective expectations. At the time of this writing, the FCS LSI was able to successfully conduct a series of tests with a MATREX-driven execution environment.

During the summer of 2005, the US Army Test and Evaluation Command (ATEC), the Training and Doctrine Command (TRADOC), and the RDECOM collaborated through the Cross-Command Collaboration Effort (3CE) to execute a portion of the Distributed Test Event – 5, a key live-virtual-constructive simulation based event supporting the Army transformation initiative (O'Conner 2006). RDECOM provided the v0.7 MATREX environment and selected components, and provided on-site technical assistance to the test execution. The simulation architecture employed for the DTE-5 was a hybrid of live TENA-based applications, gateways to legacy Distributed Interactive Simulations, and native High Level Architecture federates. The DTE-5 represented the first major milestone for the 3CE effort, and successfully demonstrated that these three organizations can collaborate with disparate modeling and simulation architectures, services and components.

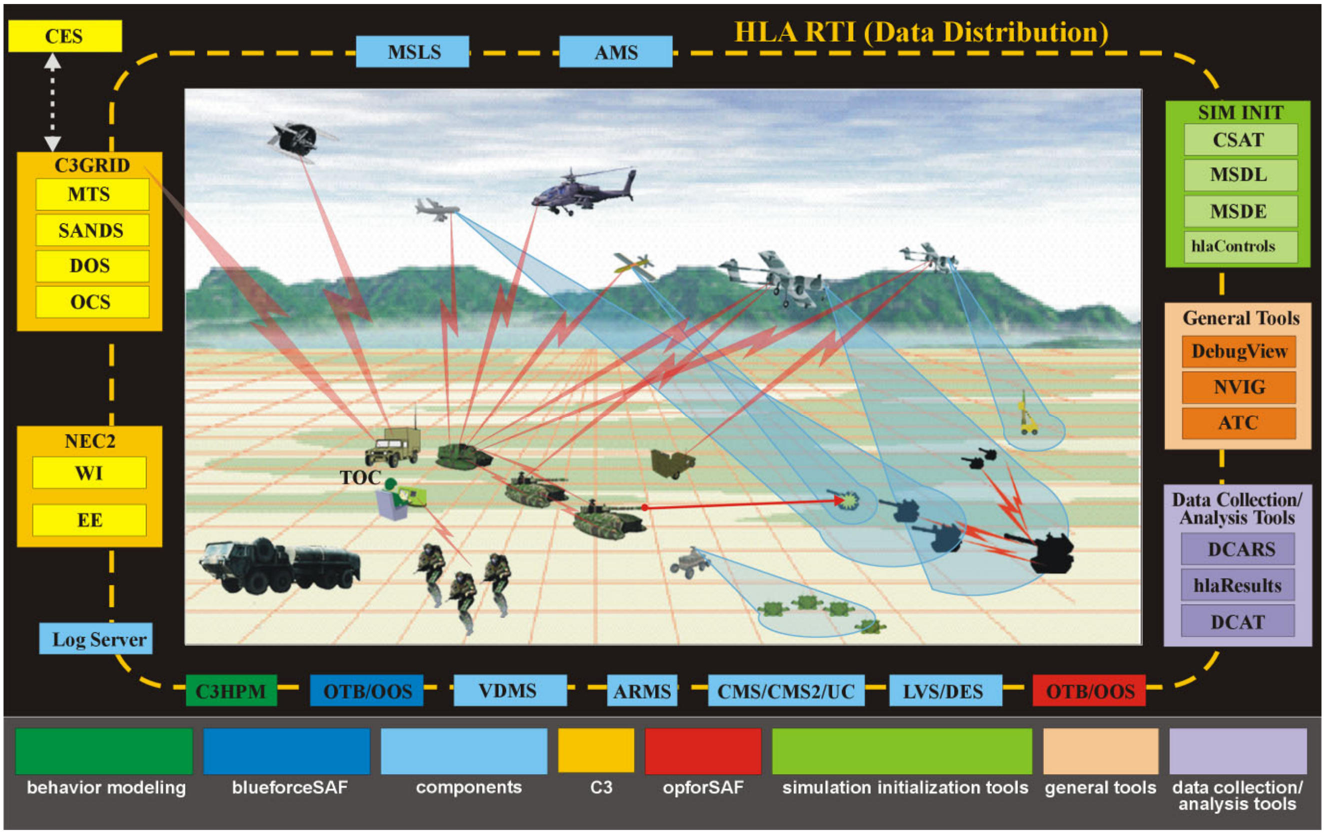

Figure 3: MATREX Reference Implementation v2.0

In 2006, two additional efforts employed the MATREX architecture: a demonstration of the MATREX survivability capabilities in a countermine scenario, and an experiment involving the MATREX Networked Effects Command and Control capability in a future force airspace management scenario. Both of these efforts utilized the MATREX core architecture and components, using products delivered incrementally after the 1.0 release. At the time of this writing, the results of both efforts are still pending.

5 CONCLUSION

The MATREX provides a unique modeling and simulation architecture for the US Army, enabling the composition of "best of breed" federations to address the technical challenges posed by the Army's transformation into network centric operations. Recent applications of the MATREX have demonstrated that the core architecture, components, tools, and supporting infrastructure are approaching a maturity level necessary to support the entire acquisition lifecycle.

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