A Distributed Systems Engineering Environment for Simulation Based Acquisition

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ABSTRACT

The acquisition of training systems with an increasing dependency on interoperability with other fielded systems presents new opportunities for the government and contractors. As training systems move from development and production into fielding, they are expected to be interoperable out of the box. Standards and protocols only provide a limited amount of confidence that interoperability is achievable, actual connectivity and testing prior to delivery is preferable to reduce risk. This paper will present a methodology for developing and maintaining a Distributed Systems Engineering Environment (DSEE) for training systems. This simulation based acquisition approach provides a capability to test system-wide concepts that previously were seen as too risky. Successful anecdotes from an existing instance of the USAF Distributed Mission Training (DMT) Development and Test Network (DTN) will be balanced against lessons learned and recommendations for the future. Foundation concepts for acquisition of diverse new training systems such as the US Army's Future Combat Systems, with affordable risk reduction through a DSEE, will be presented. Increased performance of contractors and reduced cost to the government will be discussed.

ABOUT THE AUTHORS

Mike Papay is a senior systems engineer with Northrop Grumman. He holds a B.S. and a Ph.D. in Aerospace Engineering from Virginia Tech, and has 19 years experience in the Systems Engineering community. Much of his experience in developing concepts for distributed systems engineering evolved from his most recent job as Program Manager for the Distributed Mission Training Operations and Integration program in Orlando FL.

Mike Aldinger is the Chief Engineer for Northrop Grumman Mission Systems on the Distributed Mission Training program. He holds a B.S. in Industrial and Systems Engineering from the University of Florida and a M.S. in Simulation Modeling and Analysis from the University of Central Florida. His eleven years of project management experience span facilities management, process and work design, simulation modeling, and system integration. His current roles include Standards Development Lead, and Prototype and Integration Lead for DMO federations.

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THE NEED

As the horizontal integration of systems within the DoD community increases, the acquisition of interoperable training systems becomes increasingly critical. Command, control and communications systems, as well as platforms and weapon systems, are coming under pressure to be interoperable and horizontally integrated as they are delivered. These systems are usually developed in a variety of locations, by a myriad of prime contractors and subcontractors, who are developing systems concurrently without a defined set of interface standards or Interface Control Documents.

In 1999, an Industry Steering Group supporting the Acquisition Council of the EXCIMS (Executive Committee on Modeling and Simulation) produced this SBA Vision: "An Acquisition process in which the DoD and Industry are enabled by robust, collaborative use of simulation technology that is integrated across acquisition phases and programs. The goals of Simulation-Based Acquisition (SBA) are to:

- Substantially reduce time, resources, and risk associated with the entire acquisition process;
- Increase the quality, military worth, and supportability of fielded systems while reducing total ownership costs throughout the total life cycle; and
- Enable Integrated Product and Process Development (IPPD) across the entire acquisition life cycle."[1]

The three primary components of the SBA vision are an evolved culture, a refined system acquisition process, and an advanced systems engineering environment.[1] The Distributed Systems Engineering Environment (DSEE) discussed in this paper supports all three components, in order to effectively ensure interoperability of training systems upon system delivery.

OTHER DSEE INITIATIVES

In his February 2004 paper, "The New SBA – Revisited," Von Holle discusses the validity of the SBA vision in light of DoD transformation and reaches the following conclusion: "Among the concepts, philosophies and endeavors that existed prior to the start of the transformation storm, some were swept away while others thrived. One concept that is hanging on as a potential contributor to the new acquisition environment is Simulation Based Acquisition (SBA)."[2] He also discusses a partial list of ongoing programs with an SBA-like focus, such as the Joint Strike Fighter Suite of Models and Simulations, the Joint Distributed Engineering Plant (JDEP), the U.S. Army's Simulation and Modeling for Acquisition, Requirements and Training (SMART) initiative, the U.S. Navy's distributed Collaborative Engineering Environment, and the U.S. Air Force's Joint Synthetic Battlespace (JSB). Each of these efforts is in various stages of completion, and could potentially benefit from the methodology and lessons learned which are documented in this paper.

DSEE METHODOLOGY

Our experience in developing and deploying the DSEE described in the following section enabled us to develop a set of functions that are required to successfully create and maintain such a capability. In true systems engineering form, these functions are captured in a functional decomposition in Figure 1 and discussed in this section.

Schedule Events

Distributed Systems Engineering efforts often span multiple time zones, leading to confusion about the time that the collaborative event is scheduled to start and finish.

Further complicated by the fact that when multiple companies or government organizations are involved,

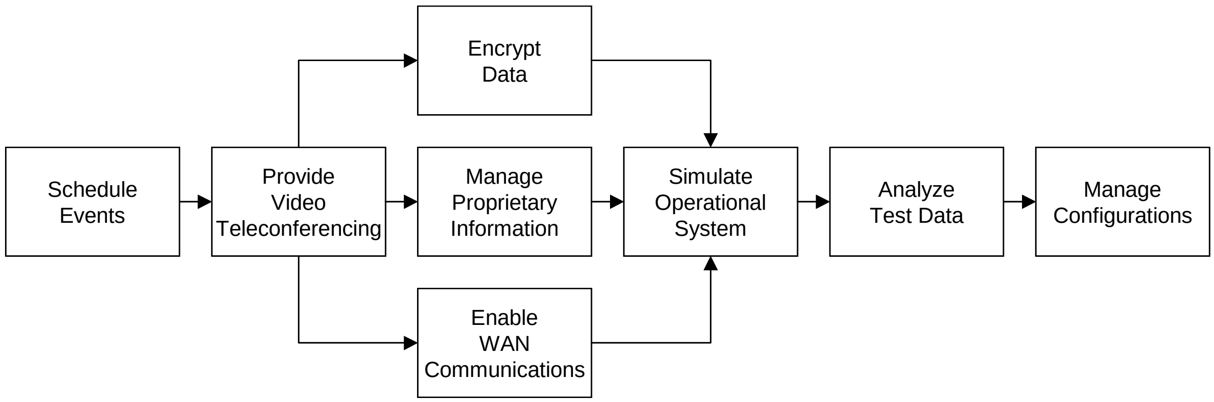

Figure 1. DSEE Functional Decomposition

they often do not share a single calendar software package which might allow easy scheduling of events, valuable engineering time is potentially wasted while one node of the DSEE sits around and waits until the proper phone calls can be made to get the remote systems engineering staff available and ready. A web-based scheduling system which is operating system and time zone agnostic, operating off Zulu time as a reference, is currently in place for the DTN, and works well.

Provide Video Teleconferencing

A basic video teleconferencing capability effectively closes communication gaps between collaborative engineering teams that rarely see each other and allows a free exchange of problem solving ideas. Other basic functions found in applications like Microsoft NetMeeting are also useful, such as a chat window, a file transfer capability, and a collaborative whiteboard.

Encrypt Data

Data that is transferred between DSEE nodes is usually encrypted, either to protect proprietary information, or to follow government regulations for transmission of classified information. In either case, a DSEE should provide the capability to efficiently and effectively encrypt data before transmitting any data outside the node.

Enable WAN Communications

The integration of Local Area Network traffic and Wide Area Network traffic ranges from simple applications such as IP traffic from a home network with a DSL or Cable Modem router all the way to a DSEE instance which emulates the real operational network being acquired or tested. Further requirements to consider when implementing this function are restrictions on corporate firewalls, bandwidth and latency required to successfully complete DSEE objectives, and the availability and expected daily usage of the DSEE WAN.

Manage Proprietary Information

From an acquisition perspective, the management of proprietary information is of paramount importance. Provisions must be planned for to carefully protect proprietary, competition sensitive, and intellectual property of the participants in the DSEE events. Starting with the successful execution of Confidential Disclosure Agreements for the parties involved and ending with an Information Technology access and password scheme that enables access without being a burden to the technical users is difficult, but achievable with the proper planning.

Simulate Operational System

If the objective of the DSEE is to simulate an operational system prior to acquisition of the program, the distributed nodes of the DSEE should replicate the actual function of an element of the final system as closely as possible. If the objective of the DSEE is instead to investigate potential interoperability issues between systems that are already being developed or fielded, the nodes have the additional burden of maintaining consistency between the fielded systems and the DSEE node in order to ensure a reliable testing environment is maintained.

Analyze Test Data

During the course of conducting distributed engineering events, large amount of test data is gathered and stored at each of the remote nodes. Adequate provisions must be made to store, analyze and archive the test data. Of particular importance are the availability of the tools used to analyze the test data. Analysis tools that examine whether the data arrived at the remote site in a properly formatted protocol, was acted upon correctly and then stored or transmitted properly often require significant development time. Careful distinctions must be drawn between the amount of time spent on testing the system and testing the testing software for the system.

System Problem Report Resolution

Once data analysis is completed, a collaborative process by which System Problem Reports are identified, assigned, prioritized, and dispositioned is critical in maintaining the momentum in the DSEE. In a complex DSEE, rapid convergence on the cause and origin of a system failure is the first step in bounding the problem. This provides a controlled test environment where the number of unknowns is minimized, reducing the number of tests and thus the overall cost of testing. In the case where analysis and team collaboration is not well entrenched, confounding of test variables may conceal the primary cause of the effect. The team's ability to understand and control the test environment directly impacts the scope of the test effort and ultimately the success of the test program.

Manage Configurations

Perhaps the single most significant impediment to progress in a DSEE is the successful management of the configurations of the hardware and software for the remote nodes. Taking "one step forward and two steps back" is often the result when good engineering analysis is executed, documented and then can't be repeated due to a minor configuration change which produces different, less desirable results.

A SUCCESSFUL EXAMPLE

The purpose of the Distributed Mission Training (DMT) Program is to allow United States Air Force (USAF) warfighters to train in the full spectrum of team combat skills. DMT is the foundation for revolutionizing training for the USAF. The DMT System supports inter-team and intra-team composite force training for warfighters located in geographically separate locations. Mirroring current doctrine, the DMT System provides warfighters the ability to train as a team, while supporting the enhancement of individual proficiency. The current training focus is on the operational and strategic training of the warfighter. The characteristics that distinguish the DMT System include:

- DMT availability is 24/7.
- Primary components are state-of-the-art, high fidelity man-in-the-loop virtual cockpits for pilots, and C2ISR crew stations.
- Supports manned threat stations that provide man-in-the-loop friendly/adversary forces.
- Provides an integrated scheduling system in support of coordinated multi-site Aerospace Expeditionary Force (AEF) training and rehearsal.
- Provides rapid mission execution in support of user training. Lead-time is 1 hour for archived scenarios.
- Mission Training Centers (MTCs) are located at home bases of aircrews.

Mission Training Centers (MTCs) are connected to the DMT System Network by an Asynchronous Transfer Mode (ATM) Wide Area Network (WAN) (Figure 2). Within the ATM WAN, virtual circuits provide connectivity between the sites as well as provide the means for continuous monitoring and control of the DMT System Network from the Network Operations Center (NOC).

The current DMT Operational Sites are: Mission Training Centers at Langley Air Force Base (AFB), VA; Eglin AFB, FL; Shaw AFB, SC; Tinker AFB, OK; Robins AFB, GA; Mt. Home AFB, ID; and Elmendorf AFB, AK.

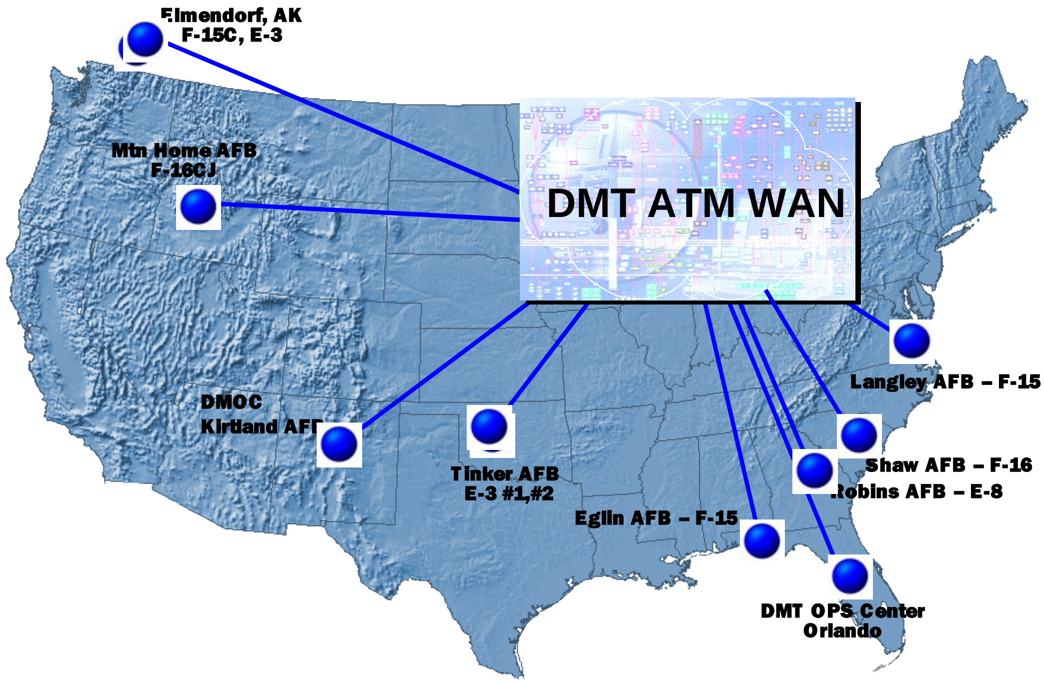

Figure 2. DMT Operational Sites

The DMT DSEE was developed to provide an integration and test environment for bringing in new and/or upgraded DMT sites. The DSEE foundation was developed around a low latency, high bandwidth network, high fidelity simulators, inter-site interoperability standards, and a robust test program. At the beginning of the DSEE effort for DMT, other alternatives were considered, such as bringing all of the equipment to a single location to perform interoperability testing before deployment, and using the operational sites as part of an integration and test environment. Both ideas were rejected as too costly:

- A single location of test equipment was unsupportable by the knowledgeable engineers that developed the virtual simulators, since every system test would involve significant travel and careful planning and coordination to ensure maximum payoff from each test.
- Using operational sites as part of the test environment was attempted during the Initial Operational Capability testing of the DMT program, and received resistance from the user community, since the test program involved using their operational training systems for a large part of the day and usurping training hours. Also, this concept still required the engineers to travel to the operational sites to support the conduct of the test, further increasing the cost.

DMT DSEE Network Architecture

The DMT DSEE network architecture utilizes the same basic structure as the operational network, which provides sufficient connectivity for all aspects of testing, and ensures that network issues are not a factor in the interoperability testing between the simulator systems (Figure 3).

Interoperability Standards

Interoperability standards apply to all Federate Systems participating in DSEE activities on the DMT System Network. Federate system sites participating in DSEE events must use federate system assets and processes that comply with effective DMT System standards criteria. DMT Standards are categorized into three areas: Interface, Process, and System Performance. Interface Standards address the network connectivity, software and hardware interfaces, and protocols necessary for federate systems to exchange information. Integration Process Standards document common processes and procedures that facilitate coordinated operation of individual simulator systems as a harmonized DMT System. Federate System Performance Standards address consistency, fidelity and performance factors, ensuring a fair fight among training participants. As a whole, the set of standards is intended to ensure an interoperable, distributed, simulated battle-training environment.

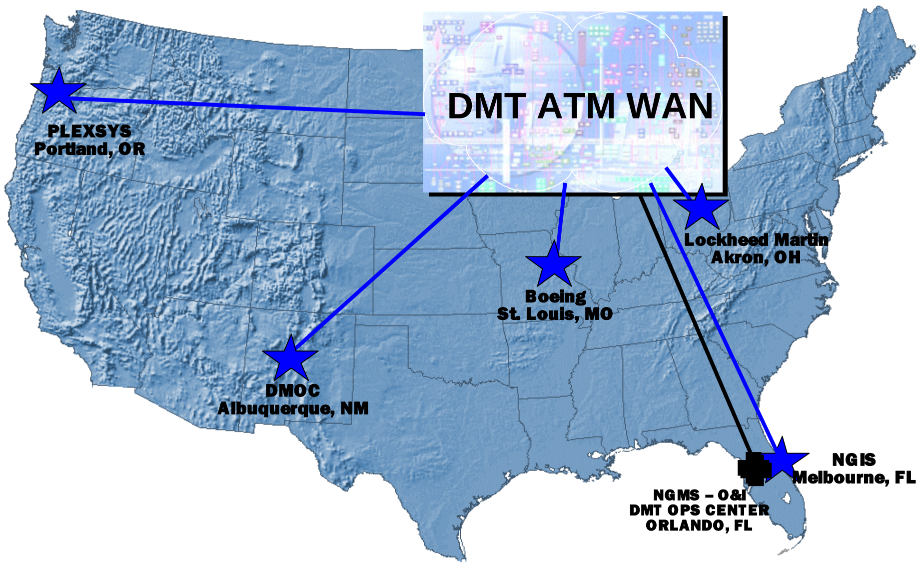

Figure 3. DMT DSEE Network

DSEE Test Process

Our approach to DSEE testing is consistent with the High Level Architecture (HLA) Federation Development and Execution Process (FEDEP); ensure validation at the site level prior to federation level testing. In the DSEE context, each DSEE node is required to adhere to the inter-site standards prior to inclusion in the test federation. This is essential in a distributed test environment, since controlling and limiting the number of variables in the test is highly correlated with conducting an efficient, successful test. Once compliance to standards is achieved, a series of simple vignettes are conducted to validate observations (e.g. entities, terrain) and interactions (e.g. communications, datalinks, detonations) among sites. Once success is achieved at this level, test scenarios are introduced to achieve a more robust battlespace. Each test activity has a pre-test and post-test telecon associated with it. In the pre-test coordination meetings, topics including go/no-go criteria, personnel issues, and security are discussed. The post-test meetings are used for achieving agreement on successes and areas of retest, SPR documentation, and scheduling follow-up activities. Information dissemination and collaboration among test participants is essential for a successful test program. This can be achieved through the implementation of web pages and message boards where participants can go for up to date test documentation or to begin a thread to initiate discussion.

LESSONS LEARNED

Standards vs Implementation

Standardization of simulation protocols such as HLA and DIS and conventions such as units of measure, coordinate systems, and battlespace representation go a long way towards simplifying the integration of disparate systems but it by no means resolves all the issues. System requirements and constraints drive the unique implementation details of each of the systems being integrated. Our experiences led us to the development of an ‘agreements’ document which specifies system settings (e.g. communication parameters, exercise ID numbers, IP addresses) to ensure DSEE interoperability test proceed smoothly. Failure to identify and establish such an ‘agreements’ document prior to test execution will lead to frustration and a poor test environment.

Test Coordination and Communication

Clear, agreed upon test objectives and a means to facilitate test activities must be established prior to test. One of the challenges we faced early in our test program was devising an effective approach for communication among test participants. Security and technical hurdles inhibited our ability to utilize phone or VTC concurrently among the test sites to coordinate initialization of test activities. The establishment of communication procedures (i.e. point-to-point calls, response timelines) was helpful in some aspects but in cases where there were multi-site issues, they were found to be ineffective. The use of a multi-point chat capability eventually provided an effective, but rudimentary, solution until the security issues were resolved.

Test Flexibility Methodology

Effective testing among multiple sites with multiple contractors requires a well-defined test plan, clear expectations, and most importantly professionalism. We have evolved our initial test approach from being dynamic and accommodating, with a focus on quick turn around for retest to a more rigid, controlled, resource focused approach where responsibility and accountability is paramount. Although flexibility and duration between tests is compromised, our efficiency has greatly improved through the implementation of go/no-go criteria, stakeholder response timelines, and resource and configuration management verification in test procedures. This has led to improved communication among participants and a clear understanding of consequences for not meeting responsibilities.

WAN Configuration

Even the best laid plans can and will go awry. DSEE nodes are connected across multiple T1 circuits to form an Asynchronous Transfer Mode (ATM) Wide Area Network (WAN). Within the ATM WAN, virtual circuits provide a means to monitor network activity. The network topology required to support the execution of a specific DSEE event is selected from a static list which initiates the activation of a particular network configuration. The use of this static list of numerous network configurations reduces human error and expedites the network activation sequence. Since network anomalies could lead to partial or complete invalidation of a test event, the implementation of procedures which include checklists and network metrics analysis well in advance of a scheduled DSEE event helps mitigate these risks. If network anomalies cannot be resolved prior to an event, the event is rescheduled.

Diagnostic tools

There are many trade-offs to be made in the selection of diagnostic tools that are applicable in a DSEE, such as inter-site compatibility, cost, and capabilities to support distributed testing. As described in the "Analyze Test Data" and "SPR Resolution" sections, collaboration among stakeholders in identifying both the root cause and the consequences of system anomalies is crucial for DSEE success. In the DMT program, the initial set of DSEE nodes utilized the set of diagnostic tools which they had implemented at the operational site due to familiarity and availability. While these attributes simplified analysis at a site, collaboration among sites was hamstrung. A better understanding of the tools implemented at the various DSEE nodes has allowed us to leverage their commonality for improved analysis and troubleshooting. In some areas, incompatibilities still exist which hampers achieving consensus on problem identification. An effort is currently underway with stakeholders to establish a suite of tools that will be used at all DSEE nodes in an effort to maximize DSEE performance.

Distribution of Resources

In the initial development phase of the DMT DSEE, having resources at several locations was a key contributor for success because scarce resources could be shared. In this instance, the prime integration contractor sent engineers to each distributed site to gain exposure to the other system configurations and obtain insight into the implementations; an invaluable benefit to future troubleshooting efforts. Resource swapping also provides a means for cross-checking and validating implementations. This experience with distributing resources among integration sites has shown high payback through quick identification of implementation inconsistencies and timely feedback in intersystem troubleshooting efforts.

CONCLUSION

The basic concepts for a DSEE, from building a solid baseline of functions to managing and maintaining the engineering environment, apply to many other emerging programs. The US Army's Future Combat System (FCS) is an example of a multi-site, multi-contractor, complex development effort that could benefit from a DSEE concept. As operational and training systems are developed for FCS, having an early start at a supporting infrastructure for the acquisition of these systems could save money, time, and resources during integration. As the horizontal integration of systems becomes increasingly important, our hope is that utilization of distributed, collaborative environments will be commonplace, bringing engineers in our community closer together to provide systems for the warfighters faster and cheaper.

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