CAF DMO Standards-Based Approach for Achieving M&S Interoperability

Michael Aldinger
Northrop Grumman Corporation
2721 Discovery Drive, Suite 100
Orlando, FL 32826
United States

mike.aldinger@ngc.com

Scott Keen
677 Aeronautical Systems Group
2300 D Street
WPAFB, Dayton OH
United States

anthony.keen@wpafb.af.mil

ABSTRACT

Distributed Mission Operations (DMO) is critical to United States Air Force (USAF) readiness and is the cornerstone of Air Force training transformation in accordance with Joint National Training Capability Initiatives as directed by the Office of the Secretary of Defense (OSD). Combat Air Force (CAF) DMO is the foundation for revolutionizing training for the USAF. CAF DMO training systems (ex. F-15C, E-3, F-16CJ, JSTARS, B-1) are comprised of high fidelity man-in-the-loop virtual cockpits for training pilots, weapon system officers, and Command, Control, Intelligence, Surveillance and Reconnaissance (C2ISR) crew stations. These Mission Training Centers (MTCs), or Federate Systems, also contain training aids which include manned threat stations, instructor-operator stations, environment generators, and Brief/De-brief solutions. The CAF DMO MTCs support both inter-team and intra-team composite force training for warfighters located in geographically separate locations throughout the world. Achieving the routine training vision for CAF DMO required the implementation of a standards-based architecture which facilitates an efficient integration and operations methodology.

The CAF DMO training architecture has been successfully implemented to provide a routine, global virtual-constructive training capability for the warfighter. With the number of CAF DMO training events in excess of 380 per year and growing, a future challenge becomes how this M&S training architecture can be expanded to support Live Range training assets and ultimately a routine DMO Live-Virtual-Constructive (L-V-C) training capability. A standards-based DMO L-V-C solution that is compatible across both Air Combat Command (ACC) and Pacific Air Force (PACAF) instrumented training ranges has been demonstrated which bridges High Level Architecture (HLA), Distributed Interactive Simulation (DIS), and Test and Training Enabling Architecture (TENA) protocols.

This paper discusses the various lessons learned associated with implementing the CAF DMO training solution for the United States Air Force. The primary foci of these lessons learned will be the development/execution of our standards development program, and the challenges associated with achieving interoperability solutions to address simulator interfaces, protocols, processes, and technical performance standards. Finally, the flexibility of this approach will be discussed to illustrate its applicability in expanding to encompass training in other domains.

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1.0 DISTRIBUTED MISSION OPERATIONS (DMO)

Distributed Mission Operations is critical to Air Force readiness and is the cornerstone of United States Air Force (USAF) training transformation in accordance with OSD-directed Joint National Training Capability Initiatives. CAF DMO is the foundation for revolutionizing training for the USAF. The CAF DMO program, also known as Distributed Mission Training (DMT), provides a training architecture that supports both inter-team and intra-team composite force training for warfighters located in geographically separate locations. The training focus is on the operational and strategic training of the warfighter.

CAF DMO Mission Training Centers (MTCs), also identified as Federate Systems in this paper, provide a capability for a platform (e.g F-15C, E-3, F-16CJ, JSTARS, A-10, and B-1) to participate in a distributed training event. These MTCs provide high fidelity man-in-the-loop virtual cockpits for pilots, weapon system officers, and C2ISR crew stations. These MTCs also provide training aids which include manned threat stations, instructor-operator stations, environment generators, and Brief/De-brief solutions. These MTCs are connected via our DMO Network (DMON); a Wide Area Network (WAN) that facilitates global connectivity between the MTCs as well as the means for continuous monitoring and control of the CAF DMO System. The CAF DMO system executes in excess of 380 distributed training events per year. Some key discriminators of the CAF DMO system include:

- Training availability is 24/7.
- State-of-the-art, high fidelity man-in-the-loop virtual cockpits for pilots, and C2ISR crew stations.
- All training systems adhere to rigid set of interoperability standards.
- Manned threat stations that provide man-in-the-loop friendly/adversary forces.
- Integrated scheduling system in support of coordinated multi-site Aerospace Expeditionary Force (AEF) training and rehearsal.
- Supports multiple/simultaneous training events.
- Rapid mission execution in support of user training. Lead-time is 1 hour for archived scenarios.
- MTCs are located at home bases of aircrews.

The primary elements of the CAF DMO architecture include the DMO Network, Interoperability Standards, Portal, and Mission Training Centers. These components are described below:

1.1 DMO Network (DMON)

The DMON is a persistent network that provides an on-demand daily training capability for CAF DMO systems. The deployment schedule for MTCs onto the DMON is illustrated in Figure 1. The DMON is a robust, scalable, secure, highly reliable network service for use by CAF DMO systems. High bandwidth, low latency, and the high availability of commercial data services are enablers for achieving our network availability goals.

The DMON implements a Virtual Private Network (VPN) that provides connectivity between the sites as well as the means for continuous monitoring and control of the DMON from the Network Operations Center (NOC). The NOC and CAF DMO Operations Center (DOC) are located at the Northrop Grumman Mission Systems (NGMS) facility in Orlando, FL. The NOC provides resources for CAF DMO Operations & Integration (O&I) personnel to conduct day-to-day operations of the CAF DMO help desk, and administer, monitor, and maintain the private network used for training exercises. The DOC operates from a secure facility located within the NOC and is capable of conducting and coordinating classified details of CAF DMO Events.

The O&I has implemented standardized site evaluation, installation, integration and test processes to meet the expansion goals of ACC. Over the past 12 months, the DMON has provided the connectivity required to facilitate in excess of 6500 training hours. In managing the network of Type-1 encryptors and the associated keying material, DMON supports multiple independent exercises at different security levels and domains.

An additional benefit of the DMON environment is that MTC developer contractor locations also have connectivity to DMON. This provides contractors a secure connection to their operational sites to perform system updates and testing without the expense of travel or special shipping of classified media. This also allows them to test with other MTC developers without taking the operational training site offline. This allows developers to test system changes with other development sites before these changes are deployed to operational sites as production builds. Over the past 12 months, contractors have logged over 1200 hours on DMON for this purpose. This type of usage has steadily increased over the years as contractors begin to realize the conveniences and savings associated with DMON use.

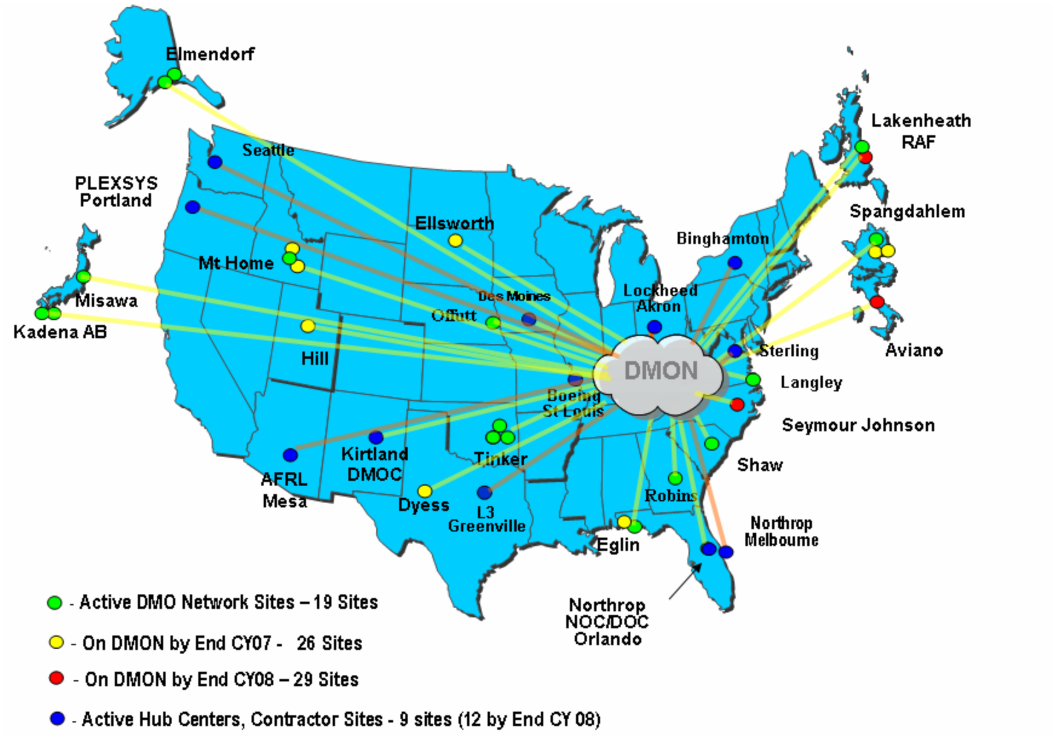

Figure 1: CAF DMO Deployment Schedule

1.2 CAF DMO Standards Development

The objective of our standards development task is to facilitate a routine, daily training capability, through the development of an overarching inter-site interoperability solution in the form of standards. These interoperability standards apply to all Federate Systems/MTCs participating in CAF DMO events being executed on the DMON. Standards are derived though a top-down process which is initiated via the identification of new training platforms and/or training requirements as defined by ACC. These requirements are then decomposed into specific technical and procedural criteria required to meet these new training needs. Implementation of these standards criteria by all CAF DMO systems provides new training capabilities for use in the CAF DMO training federation.

The collaborative development process utilized in the development of these standards is governed by the Standards Maintenance Process (SMP) as illustrated in figure 2. The CAF DMO Standards Development Working Group (SDWG) and Standards Implementation Working Group (SIWG) were established under the authority of the System Integration Engineering Team (SIET) to execute the SMP. The SDWG is a technical working group. Its primary purpose is to assess the merits of proposed standards modifications in support of the evolving CAF DMO system. Tiger Teams are tasked by the SDWG chair as necessary to develop and/or validate proposed standards modifications. Tiger Team participation is open to government, industry stakeholders, and interested community members. The SIWG's primary purpose is to evaluate the programmatics associated with a proposed standards revisions. The CAF DMO O&I contractor, as chair of the SDWG, coordinates standards publication under the authority of the Department of the Air Force Aeronautical Systems Center at Wright-Patterson AFB, Ohio 45433, contract F33657-98-D-2061.

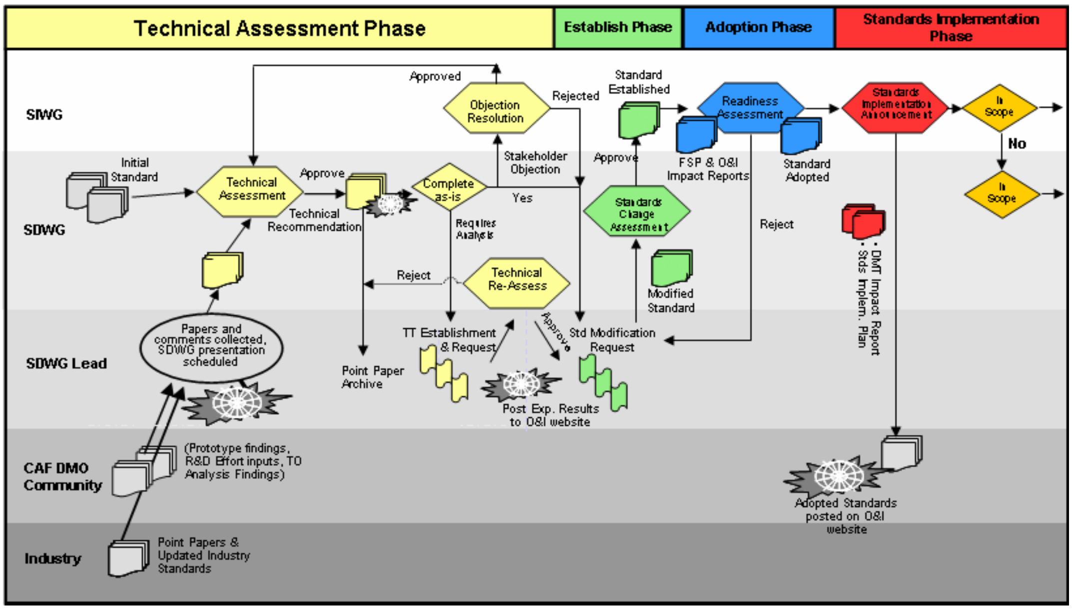

Figure 2: Standards Maintenance Process.

1.3 DMO Portal

A critical component of the CAF DMO architecture is the DMO Portal which supports the CAF DMO training system by isolating one MTC implementation from another. It also facilitates communication among MTCs which implement different simulation protocols (e.g. HLA, DIS) across the DMON, see Figure 3. Additional benefits provided by the Portal include the traffic management between MTCs, filtering invalid or unnecessary data produced by an MTC, routing traffic to MTCs based on simulation data values or needs, and a common user interface for MTCs to manage or view the status of a CAF DMO event. As the Portal evolves, its capabilities and functionality continue to increase as the CAF DMO standards expand to meet the training requirements of the CAF DMO training system. Recently added functionality to the Portal includes a state database, Dead Reckoning (DR), support for NATO EX (NEX) simulation protocol, support for multiple Local Area Network (LAN) endpoints supporting similar or disparate protocols (DIS, HLA, NATO EX, TENA), and Data Streams over the Wide Area Network.

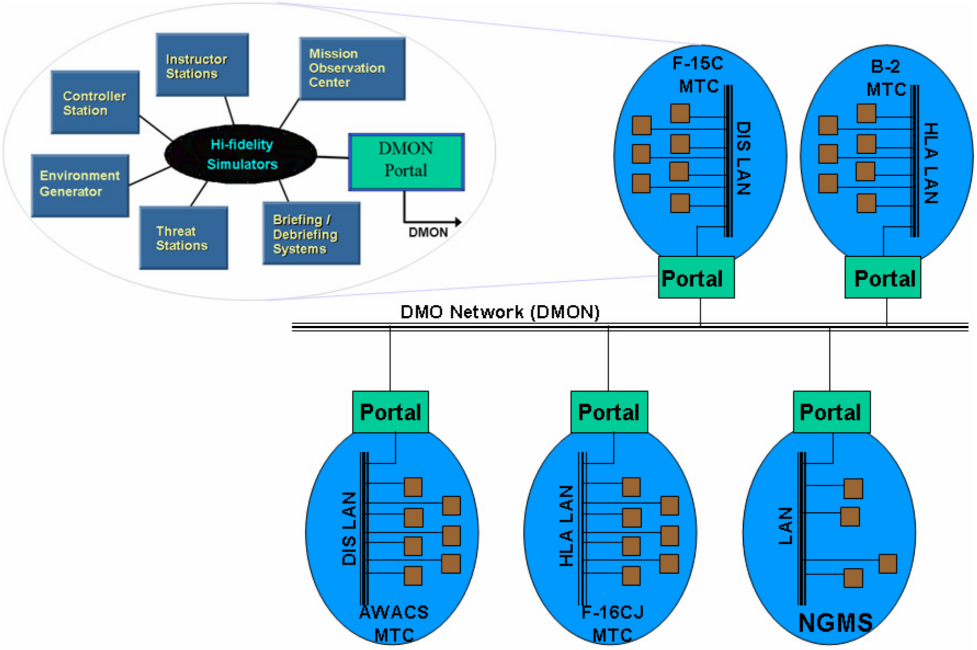

Figure 3: CAF DMO System Architecture.

Figure 4 illustrates the high-level components of the Portal architecture. MTC data is received at the LAN endpoints which provide a high-performance network interface which may be configured to filter inbound local MTC simulation traffic. The WAN Controller provides filter based routing of outbound simulation traffic (if needed) and receiving Portal Speak [e.g. Portal – Portal Protocol] from remote Portals. An MTC LAN endpoint receives all network traffic and is isolated to only listen to the desired network's traffic. Any traffic that doesn't meet the Portal's configuration for that specific endpoint is rejected prior to being received by the LAN Controller. Valid traffic is translated into Portal Speak, a protocol transmitted between Portals and representing the CAF DMO protocol standards. The Stream Manager receives standardized data packets and determines which Data Stream(s) each packet must be associated with. Packets are then duplicated and passed along to the Distributor for distribution among the remote MTC sites. With inbound simulation traffic to an MTC, the WAN Controller receives Portal Speak packets from all remote Portals listed in the configuration file. These packets are passed on to the Stream Manager to be routed to the proper LAN endpoint(s) based on the stream subscriptions. Once at the LAN endpoint, the packets are translated into the native MTC simulation protocol and sent to the network of the local MTC.

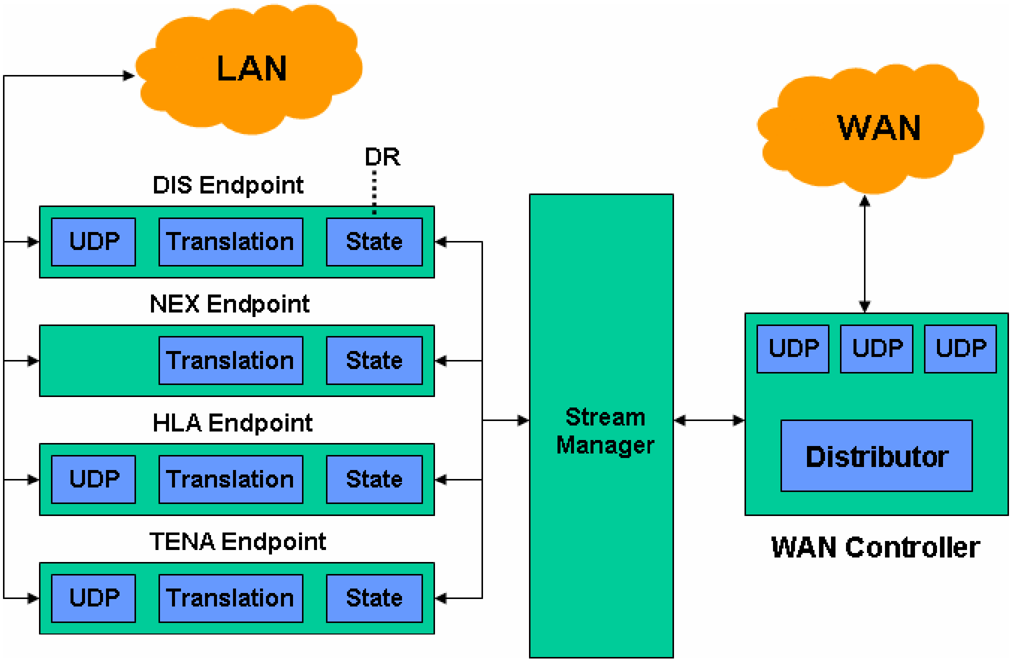

Figure 4: Portal Overview

1.4 Mission Training Centers (MTC)

CAF DMO MTCs are comprised of high fidelity man-in-the-loop virtual cockpits for pilots, weapon system officers, and C2ISR crew stations. These systems are complemented with training aids which include manned threat stations, instructor-operator stations, environment generators, and Brief/De-brief solutions. All MTCs interface to the DMON via the Portal interface specification. The interface, process/procedures, and simulation protocols utilized by these federate system sites for distributed training is in accordance with the CAF DMO standards.

The fast flyer sites (e.g. F-15C, F-15E, F-16CJ) typically contain four ownship simulators each with 360 degree visual display and an instructor operator system, four instructor threat stations, four Computer Generated Forces (CGF) Servers, a Ground Controlled Intercept/Airborne Warning and Control Station, and a Brief/Debrief System.

C2 platforms (e.g. AWACS, JSTARS) typically match the operational aircraft to include the appropriate air crew/operator workstations for crew training, Instructor Operator Stations, and a CGF to populate the battlespace.

2.0 CAF DMO INTEROPERABILITY SOLUTION

To fully realize a plug-n-play solution for CAF DMO requires the implementation of standards by all program elements. The O&I contractor's approach to achieving interoperability among the disparate Federate Systems connected across the CAF DMO Network (DMON) is through the CAF DMO System Standards (Figure 6). Participation in the CAF DMO Standards Maintenance Process provides stakeholders a voice in determining the focus and content in the evolution of standards. Through this participation, future CAF DMO participants are provided with information to assist in the development and/or integration of their Federate Systems into CAF DMO.

CAF DMO 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 MTCs to exchange information. Process Standards document common processes and procedures that facilitate coordinated operation of Federate Systems as part of the harmonized CAF DMO system. Federate System Performance Standards address consistency, fidelity and performance factors, ensuring a fair fight among training participants.

Standards Category	Interoperability Standard
Interface Standards	Network (incl Portal) DMT Tailored DIS Reference Federation Objective Model (FOM)
Integration Process Standards	Event Control Security Conformance Testing Data Sharing
Federate System Performance Standards	Technical Performance Synthetic Natural Environment (SNE) Threat Representation and Computer Generated Forces Common Models Visualization

Figure 6: CAF DMO Standards

Stakeholders interested in conducting or participating in CAF DMO training events must use Federate Systems and processes that comply with effective CAF DMO System standards criteria. Once a Federate System meets these standards, they are "Certified" for participation on the DMON to begin system integration activities. Once a Federate System is successfully integrated into the CAF DMO training federation, no further integration testing is required for participation in that training federation. The 12 standards with criteria effective for the CAF DMO training federation are those necessary to achieve CAF DMO training objectives with the integrated capabilities of the available Federate Systems in a DIS and HLA compliant network.

Below are brief descriptions of the CAF DMO standards identified in figure 6.

2.1 Network Standard

The DMON is a complex system consisting of the Northrop Grumman Portal, network equipment, encryption devices, and a commercial Wide Area Network (WAN). The Network Standard specifies criteria that define the protocols, physical connections, and facility requirements needed to interface with the DMON. Federate System Providers must adhere to the criteria outlined in this standard to ensure reliable and repeatable network connections. In addition, the Network Standard defines criteria for network applications that do not readily fit within other CAF DMO Standards.

2.2 DMT/CAF DMO Distributed Interactive Simulation (DIS) Standard

The CAF DMO Tailored DIS Standard is based on the IEEE DIS 1278.1a standard. It describes the specific implementation of DIS in the CAF DMO environment. The standard is the reference for CAF DMO protocols that are subject to interpretation in or anticipate changes to the IEEE 1278.1a standard. These Simulation Interoperability Standards Organization's (SISO)-based standards have been tailored to address the high fidelity training requirements necessary to meeting ACC inter-team training objectives.

2.3 High level Architecture (HLA) Reference Federation Object Model (RFOM) Standard

The CAF DMO RFOM Standard provides guidance for implementing the CAF DMO RFOM for HLA-based simulations. It is based on the SISO-STD-001 Real-time Platform-Based, Reference FOM (RPR-FOM). It also incorporates the Link 16 BOM described in SISO-STD-002 and ASTi Simulation Object Model (SOM) for radio communications.

2.4 Security Standard

The CAF DMO Security Standard includes all aspects of system security. The focus is on compliance with existing National, Department of Defense, Air Force and commercial security doctrine, directives, instructions, and practices. The CAF DMO System Security Standard depends heavily on the DOD Directive 5520.22-M, National Industrial Security Program Operating Manual (NISPOM) to identify required system-level security services to be provided by the CAF DMO Network. Additionally, Information Assurance criteria for COTS and GOTS products are found in both industry and government specifications programs. The Common Criteria, the Joint Technical Architecture (JTA), and the Defense Information Infrastructure Common Operating Environment (DII COE) provide guidelines for Automated Information System's individual and system-level hardware and software components. Some of these components by their nature define system-level standards. The TACLANE in-line network encryptor, for example, serves as the component that satisfies the Public Law requirement to use a "NSA Approved, Type 1 Encryptor" to protect classified National Security information transmitted between the physical boundaries of two or more approved facilities.

The CAF DMO Security Standard addresses the development of Security Test and Evaluation procedures applicable to all of the planned Federate Systems and approved by the Designated Approval Authority (DAA). Compliance with all features of the standards shall be demonstrated and documented through the Certification and Accreditation processes described by both the NISPOM and by AFSSI 5024.

2.5 Event Control Standard

The CAF DMO Event Control Standard addresses required automated and procedural activities that the O&I and each participating MTC must perform to organize, manage, and control a distributed training event. This standard addresses DMON test and training event planning, scheduling, scenario generation, initialization, execution, monitoring, and close out. The roles and responsibilities for coordination and production of mission data needed to support all of these activities are defined in the standard.

2.6 Data Sharing Standard

The CAF DMO Data Sharing Standard addresses all data sharing and collection considerations that require cooperative and/or interoperable support among DMON sites not provided within the context of other CAF DMO standards. For example, information conveyed by simulation protocol in direct support of simulation execution is governed by the Tailored DIS and RFOM standards, but standardization of log file content and format for the purpose of supporting common analysis tools or shared playback control techniques would fall under this standard. In general terms, this standard includes criteria governing the sharing and collection of data to support mission planning, briefings, run-time analysis, post event analysis and debriefing, and generation of after-action review products. This standard identifies the data to be shared, how it will be collected, how it will be made available, where/how the data will be transferred, in what formats it will be transferred and/or stored, what access controls will be applied, how the data will be organized, what access methods will be available, and how it will be viewed/displayed.

2.7 Common Models Standard

To function together in a common synthetic battle environment, Federate Systems share data specified in the Tailored DIS and RFOM Standards across the DMON according to the CAF DMO Network Standard. Federate System simulations must act upon this shared data, as well as local data, in a way that provides the best possible training value to CAF DMO participants. Of specific concern is that models of related or common phenomena, events, and actions perform with sufficient similarity across the various Federate Systems that collective training goals are achieved. Where necessary to ensure interoperability and consistency of representation for phenomena, events and action across the CAF DMO battle space, the Common Models standard will specify algorithms, models, and/or related parameters and constraints for Federate Systems to use in common within their simulations.

2.8 Conformance Testing Standard

The Conformance Testing Standard defines the process, documentation and personnel required to accomplish each level of the standards conformance testing process and assigns responsibilities to the CAF DMO O&I Contractor, CAF DMO Federate Sponsors and CAF DMO Federation Sponsors. This standard defines the processes to be followed to ensure CAF DMO Federates and Federations comply with the various CAF DMO System Standard criteria and are able to interoperate over the DMON.

2.9 Threat Representation & Computer Generated Forces Standard

Environment Generators are essential to filling out the virtual battlespace and creating a realistic training environment. The threat models must be consistent in fidelity and behavior, or the quality of the training could be adversely affected. In addition, management of the distributed CAF DMO network demands that the CGF systems include adequate control functionality and common interoperable protocols for invoking them. The Threat Representation and Computer Generated Forces (TRCGF) Standard addresses these issues, and imposes conformance criteria on CGF systems to insure they meet these expectations.

The TRCGF Standard addresses such issues as transfer ownership, the ability to interact appropriately with external battlespace entities, and battlespace consistency with respect to aircraft performance, radar performance, missile performance, and missile engagements. Future considerations include additions or refinements in the areas of consistency (e.g., weather), and enhanced simulation management functions or capabilities (e.g., more detailed transfer ownership requirements, entity update message metering).

2.10 Technical Performance Standard

The Technical Performance Standard ensures that Federate Systems meet critical technical performance requirements that are necessary for the CAF DMO System to operate properly. The Technical Performance Standard establishes criteria ensuring consistency and interoperability of Federate Systems supporting CAF DMO events. All Federate System components that interact with the CAF DMO distributed simulation battlespace are included in the scope of the Technical Performance standard, including pilot stations (i.e., ownships), threat stations, instructor operator stations (IOS), console stations and computer generated forces systems (i.e., environment generators).

The Technical Performance Standard address such issues as emissions representation, tracked munitions representation, and simulation protocol parameters. Future considerations include simulation modeling parameters, simulation device survivability and graceful degradation with respect to battlespace scalability, and robustness with respect to non-standard simulation messages.

2.11 Synthetic Natural Environment Standard

The Synthetic Natural Environment (SNE) standard specifies criteria that if met by CAF DMO participating Federate Systems will ensure SNE database consistency and correlation required to ensure Federate System interoperability.

The SNE database of a Federate System characterizes the terrain surface, objects on the terrain, such as buildings, lighting and other cultural features that lack active behavior, and also weather and atmosphere. Terrain characteristics of concern for interoperability include shape, land cover appearance, land condition (e.g., dusty, wet), and reflectivity properties throughout the spectrum. Object characteristics include type (identity), existence, location, orientation, and appearance. Atmospheric and weather parameters include representation of wind, rain, lightening, haze, etc. Other characteristics may be addressed in the standard as necessary to achieve interoperability.

2.12 Visualization Standard

The Visualization Standard specifies standards criteria regarding the performance and capabilities of the visual systems associated with virtual simulators as they interpret the Synthetic Natural Environment database content to present scene content. These criteria are formulated to minimize differences in scene content and appearance that would materially affect trainees' perception of the environment from one simulator to the next.

The visual system applies algorithms to turn SNE data into visual effects. Important factors in a scene such as lighting and darkness, shadows, haze, clouds and dust are largely controlled by the technical capabilities of visual system components rather than data in the SNE database. The Visualization Standard is directed at ensuring that variation in these common effects as produced by different visual systems do not introduce negative training side-effects.

3.0 LESSONS LEARNED

During the past eight years, the CAF DMO program has continued to evolve to meet the needs of the warfighter. Some to this evolution was due to program growth while other changes would be better characterized as growing “pains”. In developing our standards-based architecture, we have experienced a number of challenges that had to be overcome. The paragraphs below briefly discuss some of the lessons learned experienced in implementing the CAF DMO architecture.

3.1 Standards Guidance

The IEEE DIS standard does an outstanding job in both defining requirements and providing guidance in many areas. The DIS standard promotes interoperability across training domains and provides guidance where different fidelity levels drive different solutions. The CAF DMO Standards Development Working Group has utilized this guidance in the development of explicit requirements (e.g. beam modeling, entity ID reuse, transfer ownership, heartbeat timers, jamming, emissions) which address the interoperability needs of CAF DMO. This includes the need to interoperate with air, sea, and ground systems involved in large scale exercises (e.g Virtual Flag). These DIS changes have been submitted to IEEE and are currently being addressed as Problem/Change Requests (PCRs) by the DIS Product Development Group. Participation in standards organizations is critical for maximizing program growth potential while reducing costs associated with this growth.

3.2 Network Architecture

An extensive amount of human resources is required to support the network configuration and system maintenance needs necessary to support distributed daily training events. To improve both efficiency and reliability of our CAF-DMO network solution, we have migrated our network implementation from an ATM to VPN-based solution. This Multi-protocol Label Switching (MPLS) network solution, designed in conjunction with our network service provider, provides dynamic network set-up/configuration, optimal routing, and dynamic bandwidth allocations among MTCs. This solution not only improves network performance but minimizes the human element, thus reducing configuration errors.

3.3 Standards First Policy

At IOC (Initial Operational Capability), each participating MTC (e.g. F-15C, E-3) had been developed to support their specific intra-team training needs without common standards guidance. The result was highly efficient training systems which were focused on achieving the specific ACC intra-team training objectives for their platform. From a CAF DMO "System of Systems" perspective, this resulted in an outcome that was not readily capable of supporting distributed inter-team training. At the time, the CAF DMO systems lacked the interoperability solutions required for inter-team training due to 1) Differing approaches executed in implementing platform functionality, and 2) the lack of additional MTC functionality required to support inter-team training requirements.

To rectify this issue and thus maintain a controlled test environment where effective test and evaluation can be conducted, we required that Federate Systems/MTCs under test are "Certified" as compliant to the effective standards prior to test activities. Our experience has shown that time lost during standards certification activities will be easily recouped through a test environment where the majority of the unknowns have been resolved, through certification, prior to test. This controlled test environment greatly simplifies the identification and resolution of test anomalies.

3.4 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 specify the necessary system settings (e.g. communication parameters, exercise ID numbers, IP addresses) required to ensure DTN and Operational interoperability tests proceed smoothly. Failure to identify and establish such 'agreements' prior to test execution will lead to frustration and an uncontrolled test environment.

3.5 Integration & Test Methodology

The use of operational sites as part of the test environment was attempted during the IOC testing. This approach, although successful in achieving our IOC integration objectives, 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. Other issues such as test flexibility, and resource and configuration management constraints also contributed to making this approach untenable.

Our alternative approach, the Distributed Test Network (DTN), is an expansion of the DMON to encompass contractor development sites. These development nodes, or MTC surrogates, are required to adhere to the CAF DMO 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 exercise 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, areas for retest, System Problem Report 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 of new topics.

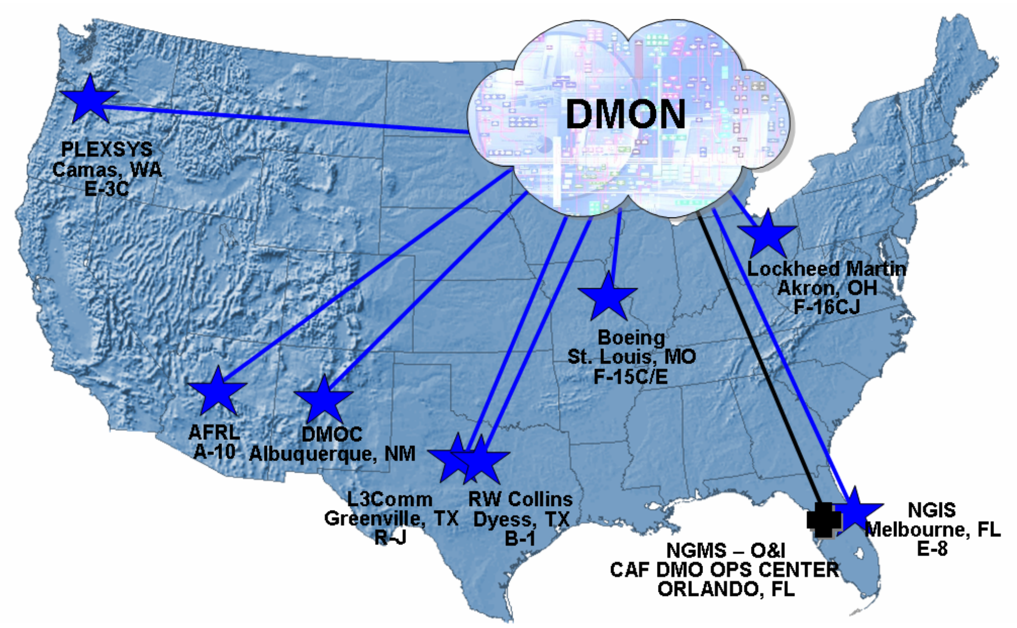

Figure 5: CAF DMO Distributed Test Network.

3.6 Details Matter

Clear communications and dynamic visual representation provides an impressive presentation for the casual observer, but when effective training is the objective, the devil is in the details. A DTN type solution provides an optimal means for analyzing and identifying interoperability issues which are subtle and difficult to isolate. Some of these interoperability issues whose identification can be attributed to the DTN environment include emission parametric values, Link-16, and terrain and target correlation. Only after thorough data logging and analysis were these issues clearly understood and addressed.

3.7 Configuration Management (CM)

In early test efforts, the lack of a coordinated system-wide CM plan resulted, at times, in an uncontrolled test environment. In many ways this defeated all the other SE focused elements of Integration & Test (I&T) program. An example of this would be a build revision is installed but not reported due to its perceived benign nature. The result at times was different behaviors or representations being displayed among the test sites which degraded confidence in the system and slowed integration progress. To mitigate these types of issues, a Configuration Control Board was been stood up to coordinate the various CAF DMO system updates among program elements.

3.8 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 Video Teleconferencing 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. Our current, and most effective approach, is the implementation of VoIP phones among all CAF DMO Federate System locations.

3.9 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 led to improved communication among participants and a clear understanding of consequences for not meeting responsibilities.

3.10 Diagnostic tools

Collaboration among stakeholders in identifying both the root cause and the consequences of system anomalies is crucial for program success. In the CAF DMO program, the initial set of MTCs utilized the set of diagnostic tools that they had implemented at the operational site due to familiarity and availability. While these attributes simplified analysis at a site, collaboration among sites was very difficult. A better understanding of the tools implemented at the various test sites has allowed us to leverage their commonalities for improved analysis and troubleshooting. In some areas, incompatibilities still exist which hampers achieving consensus on problem identification. These issues are being addressed in the SDWG through updates to our Data Sharing Standard.

3.11 Distribution of Resources

In the initial development phase of the CAF DMO, having resources at several locations was a key contributor for success because scarce resources could be shared. In this instance, Northrop Grumman 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.

4.0 APPLYING STANDARDS METHODOLGY BEYOND CAF DMO

The continued emphasis on both joint training and integration with other training domains (e.g. Live) has led us into endeavours beyond the familiar Virtual-Constructive confines of the CAF DMO program. Recently ACC tasked Northrop Grumman to leverage our standard-based architecture in coalition, live domain, and other service platforms to include integration of US Army's Apache trainer.

Through implementation of our top-down development approach, we implemented a standards based DMO L-V-C solution by implementing a TENA Portal that is compatible across both ACC and PACAF instrumented training ranges. To achieve this objective, the Portal provided an interoperable solution among TENA, HLA, and DIS implementations. The four phases of the L-V-C environment we provided interoperability solutions for are: DMON Interface Definition and TENA TSPi, Voice/Audio data, L-V-C Link-16 Datalink, and Beyond Visual Range Weapon Simulations Interface. The products of this effort were the development of an initial DMO L-V-C capability and an associated set of candidate standards to govern a routine DMO L-V-C training environment. PACAF has recently placed Northrop Grumman under contract to leverage the ACC L-V-C effort to implement a standards-based L-V-C solution for PACAF Alaska ranges.

Regarding coalition efforts, our standards-based architecture is currently being leveraged to establish a DMON connection to Royal Air Force - Waddington in support of a US-UK proof of concept. Communication among the training systems will be facilitated through DMON Portals. This proof of concept will demonstrate the potential for training coalition events in the standards-based, "daily" training environment of CAF DMO.

5.0 CONCLUSION

With the growing need for M&S training solutions to address new training domains and services, we face new interoperability challenges that must be efficiently and effectively mitigated. Through collaboration with stakeholders, involvement in the international standards community, and ingenuity, we believe standards-based training architectures can be leveraged to meet this challenge. Our hope in writing this paper is that other communities will benefit from what we have learned and implemented regarding standards-based training solutions.