Achieving Standardized Live-Virtual Constructive Test and Training Interactions via TENA

Joseph Testa
DRS Training & Control Systems, Inc
Fort Walton Beach, FL
jtesta@drs-tcs.com

Mike Aldinger
Northrop Grumman
Orlando, FL
mike.aldinger@ngc.com

Kris Wilson
DRS Training & Control Systems, Inc.
Fort Walton Beach, FL
kwilson@drs-tcs.com

Christopher Caruana
FAAC Incorporated
Ann Arbor, MI
caruana@faac.com

ABSTRACT

Various implementations of Live, Virtual, and Constructive (L-V-C) interactions have been demonstrated across numerous test and training ranges over the past few years. However, the virtual world remains largely disconnected from everyday live test and training activities. The Test and Training Enabling Architecture (TENA) standard being adopted by the soon to be fielded P5 Combat Training System and the next generation Enhanced Range Application Program presents a host of possibilities for standardized live virtual interactions. The Air Forces Combat Air Force (CAF) Distributed Mission Operations (DMO) Office, responsible for a distributed, interoperable, high fidelity, global training solution for virtual-constructive Mission Training Systems, is currently implementing a TENA interface as part of their DIS-HLA Portal solution. This TENA Portal has the potential to link the P5 CTS, EnRAP and DMT systems via a standard TENA interface.

This paper identifies, reviews, and analyzes the current DMO L-V-C effort and near term opportunities to provide live virtual interfaces between live P5 CTS and EnRAP systems and virtual CAF DMO systems utilizing the TENA standard. These interactions' would allow real-time live entities to be brought into the DMO virtual domain, and likewise, DMO entities brought into the live test and training domain. The interactions of live and virtual entities via TENA would be initially limited to audio, positional data, and weapons engagements; however, this level of interoperability represents a first step in realizing a standardized and affordable approach to achieving L-V-C test and training operations. This paper will also describe several efforts that would increase the fidelity of Live-Virtual interactions via a TENA standard interface.

ABOUT THE AUTHORS

Joseph J. Testa is the DRS Training and Control Systems principle engineer assigned to Strategic Plans and Programs. He has 20 years of systems engineering experience of which the last 13 years are specific to range systems. He also has 20 years of USMC tactical flying experience. Mr. Testa holds a B.A. in Physics from Glassboro State College and in an active member of NDIA/NTSA.

Mike Aldinger is the Chief Engineer for Northrop Grumman Mission Systems on the Combat Air Force (CAF) Distributed Mission Operations (DMO) program. He holds a B.S. in Industrial and Systems Engineering from the University of Florida and an M.S. in Simulation Modeling and Analysis from the University of Central Florida. His current roles include DMO Standards Development Lead, DMO-Space Chief Architect, and DMO L-V-C Task Lead.

Kris N. Wilson is the DRS Training and Control Systems Principle Engineer for Advanced Programs. He has over 20 years engineering experience with Test and Training range systems. Mr. Wilson holds a triple Major Bachelor of Individualized Study at the George Mason University colleges of Computer Science (Software Engineering), Electrical Engineering (Digital Design) and Business (Management).

Christopher J. Caruana is a Senior Engineer at FAAC Incorporated in Ann Arbor, MI. He is the Program Lead for all training range weapon and electronic warfare simulation products produced by FAAC. Mr. Caruana holds a B.S.E. and M.S.E. in Aerospace Engineering from the University of Michigan.

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Joseph Testa	Mike Aldinger	Kris Wilson	Christopher Caruana
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LIVE-VIRTUAL-CONSTRUCTIVE SYSTEMS, INTERACTIONS, AND TEST AND TRAINING BENEFITS

In the past, the test and training community depended heavily on the operation of live operational systems at open air ranges as the only realistic media for conducting test and training activities. Today, due to dramatic improvements in the capability and affordability of advanced distributed simulation technologies, test and training effectiveness can be significantly improved at the mission and team level using the concept of distributed simulations. It allows participation, using networkable training devices, from various platforms contained within numerous combat mission areas. Additionally, computer-generated, or constructive, forces can be used to substantially enhance the scenario. This combination of live, virtual, and constructive environments will allow nearly unlimited training opportunities for joint and combined forces from their own location or a deployed training site. This distributed capability provides on-demand, realistic test and training opportunities without many of the fiscal, geographical, safety, geopolitical, and range scheduling problems associated with a "live range only". (Brower, 2003) To help understand the concept of Live-Virtual-Constructive interactions as described in this paper, a review of some definitions is appropriate. Commonly accepted definitions of live, virtual, and constructive systems are provided as follows:

- **Live Systems** – Live system involve real systems operating with real people in the real world. An example is air combat training where real aircraft are operating in the real world against real advisories.
- **Virtual Systems** – Virtual systems involve real people operating real equipment that simulates a platform in a simulated environment. An example is an Aircraft Trainer where real pilots operate a trainer that simulates a real aircraft operating in the real world.
- **Constructive** – Constructive systems involve simulated people in a simulated environment, all entities and activities are simulated. Constructive simulations are typically used at theater and command level training scenarios.

Integrating Live, Virtual, and Constructive, systems to provide a meaningful training environment is many times difficult to achieve because live players are subjected to virtual and constructive simulated environments which they cannot visually see; and likewise, live sensors cannot sense, simulated entities. Both visual and sensor stimulation is required for live players to interact with simulated entities, which is usually not available to currently fielded tactical platforms. However, next generation aircraft currently in development are working this problem through incorporating an "embedded training" capability within the aircraft allowing aircraft sensors to detect and display simulated entities to the pilot. Even with this live player problem, there are test and training scenarios where L-V-C interactions can provide meaningful training and help achieve the Department of Defense goal of high fidelity, cost effective, test and training capability. Integrating L-V-C systems enhances the realism of test and training scenarios and can also provide scenarios difficult to achieve with only live systems. Although not exhaustive, the following L-V-C test and training scenarios (Table 1) provide obtainable and effective applications of L-V-C.

The combination of live, virtual, and constructive environments should provide on-demand, realistic scenarios that overcome many current constraints that limit the effectiveness of today's test and training capabilities. A generic L-V-C capability is depicted in Figure 1.

Table 1. Test and Training Integrated L-V-C Scenarios

Systems Interactions	Scenarios	Advantages	Participants
Live – Virtual	Virtual C2ISR platform controlling live entities	(1) Increased training for C2ISR aircrew (2) Increased availability of C2ISR training for live fighters	- Live Fighters - Live Opposing Fighters - Virtual AWACS
Live – Virtual - Constructive	Virtual C2ISR platform controlling live and virtual entities with constructive ground threats	(1) Increased training for C2ISR aircrew (2) Increased availability of C2ISR training for live fighters (3) Increased fidelity of C2ISR problem (4) Increased mission fidelity for live players	- Live Fighters - Live Opposing Fighters - Virtual Fighters -Virtual Opposing Fighters - Constructive Ground Threats
Live – Virtual	Virtual IADS controlling live ground threats	(1) Provides increased fidelity of ground threats without the cost of a live IADS	- Live Fighters - Live Ground Threats - Virtual IADS
Live-Virtual-Constructive	Virtual IADS controlling live and constructive ground threats	(1) Provides increased fidelity of ground threats without the cost of a live IADS or live ground threats	- Live Fighters - Live ground threats -Virtual IADS -Constructive Ground Threats*

*Requires stimulation of live aircraft RWR equipment supporting constructive ground threats.

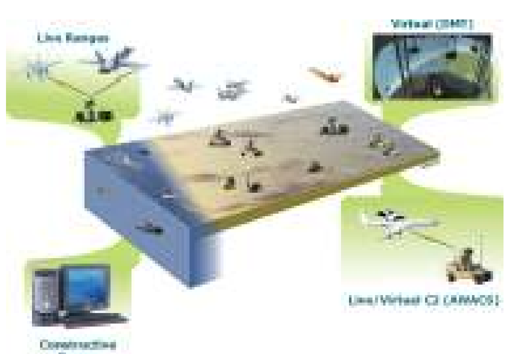

Figure 1. L-V-C Test and Training Environment (MS061057)

THE TEST AND TRAINING ENABLING ARCHITECTURE (TENA)

The United States Department of Defense (DoD) has invested billions of dollars in geographically dispersed, air, land, and sea, test and training, ranges. As these DoD ranges expanded in mission types and acquired resources, each range tended to develop "vertically", each building on unique range-dependent instrumentation systems. This isolated growth defeated the economic and efficiency gains that could be achieved by range resource reuse and range interoperability, concepts that were being forwarded in the late 1990s by the Foundation Initiative 2010 (FI 2010) project, which was sponsored by the Office of the Secretary of Defense (OSD) Central Test and Evaluation Investment Program (CTEIP). (Hudgins, 2005)

FI 2010's Test and Training Enabling Architecture (TENA), see Figure 2, became a technical blueprint for achieving that vision of an interoperable, reusable, and composable set (composibility is defined as the ability to rapidly assemble, initialize, test, and execute a system from members of a pool of reusable, interoperable elements) of geographically distributed range resources, some live and some simulated, that can be rapidly combined to meet new testing and training missions in a realistic manner. With the close-out of the FI 2010 project, the sustainment and future modernization of TENA has been transferred to the TENA Software Development Activity (SDA), under the Test Resource Management Center (TRMC), with sponsorship from CTEIP, and the U.S. Joint Forces Command (USJFCOM) Joint National Training Capability (JNTC). (Hudgins, 2005)

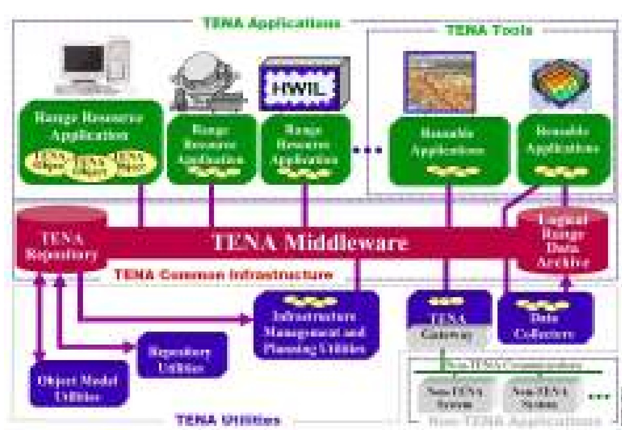

Figure 2. TENA Overview (Hudgins, 2005) (MS061056)

Adoption of the TENA Standard Architecture

TENA has become an important interoperability enabler in JNTC military exercises. In March of 2004, Major General Gordon C. Nash, then United States Marine Corps Commander, Joint Warfighting Center and Director for Joint Training, USJFCOM, spoke before the House Armed Services Subcommittees on Readiness, Terrorism, Unconventional Threats, and Capabilities of the JNTC. Addressing range instrumentation as a part of the progress in implementing the JNTC, Maj. Gen Nash said that JNTC was playing a key role in upgrading instrumentation systems employed on the many service ranges used for test and training throughout the country. "These upgrades, employing a consistent set of standards and protocols, are ensuring a level of service interoperability never seen before. Additionally, through the investment incentive offered by the JNTC Joint Management Office, modernization of service-centric range instrumentation and telemetry systems is moving forward at an accelerated pace. Modern instrumentation systems will comply with the Test and Training Enabling Architecture (TENA), an architecture and interoperability standard that shares information among instrumentation systems, simulations, and real-world command-and-control systems."

The architecture "steering" the TENA activities identifies a number of products needed for a complete realization of the TENA vision. The TENA Middleware provides the software foundation for many of the other architectural products and concepts. A brief description and status of the key TENA products is shown in Table 2.

TENA Exercises Supporting L-V-C

In January 2004, the JNTC conducted a large-scale military exercise, the Western Range Complex (WRC) Horizontal Training Event. Designed to test and evaluate warfighters and warfighting concepts, the exercise spread its personnel, equipment, data gathering, and distribution networks from coast to coast. Exercise participants included Fort Irwin and Twenty-nine Palms ranges in California and the USJFCOM in Suffolk, Virginia, with several exercise and data points scattered between the two coasts in Nevada, New Mexico, Kansas, Alabama, Florida, and Georgia.

Hundreds of air sorties and days of ground maneuvering played out the various scenarios as exercise data flowed from several disparate instrumentation systems: TENA was designated by JNTC to "connect" these individually distinct systems and the geographically separated ranges and allow a smooth data flow to TENA-enabled displays and data analysis points.

Table 2. Key TENA Products and Current Status

Product Name	Purpose	Status
TENA Middleware	SW connecting distributed applications.	Approximately eight middleware releases over the last five years.
TENA Object Models	Object models are used to define the information	Approximately 500 user object models currently exist within the repository.
TENA Repository	A common web accessible storage facility for user event artifacts	The TENA Repository currently supports the user community with an initial focus on object models.
TENA Data Archive	A common archive	Work is planned for this capability.
TENA Object Model Utilities	Software utilities to support the creation and refinement of object models.	A client-side development tool, TENA Integrated Development Tool (TIDE) supports object models.
TENA Execution Management Tools	Tools used for management of TENA executions.	The Application Management Object (AMO) supports runtime management operations

That coast-to-coast connection of range instrumentation systems and ranges met a major milestone on the road to true range interoperability and range resource reuse in the JNTC 2004 exercises.

The Jan 2004 WRC exercise was the first pre-initial operating capability, Live, Virtual, and Constructive (L-V-C) event conducted by the JNTC. The event's live activities were conducted on the United States Western Ranges in conjunction with a U. S. Army National Training Center (NTC) rotation, a U.S. Air Force Air Warrior segment, and a U. S. Marine Corps Combined Arms exercise (CAX) at Marine Corps Station Twenty-nine Palms, California. The integration and instrumentation solution linked the exercise locations using TENA. Live air and ground tracks from the NTC, Nellis AFB (Air Warrior), and Twenty-nine Palms ranges were integrated and then distributed to USJFCOM to create a L-V-C Joint training environment.

Joint Red Flag 2005 (JRF05) made extensive use of TENA. The exercise included over 10,000 participants and was a standard Air Force Red Flag exercise run in conjunction with an Army Roving Sands Exercise combined into a Joint National Training Capability (JNTC) event. It involved live, virtual, and constructive components and was reported to be the largest integrated exercise utilizing live and virtual simulations. (Hudgins, 2005)

TODAY'S INSTRUMENTAL TRAINING RANGES

For thirty years, the Air Force and Navy have relied on instrumented training systems at open-air ranges to develop and maintain the combat skills needed to dominate any battle-space. Through a progression of enhancements, Air Combat Training Systems (ACTS) have become an essential means of ensuring that Air Force and Navy aircrews are ready to implement orders from the National Command Authority. Increased emphasis on US joint training by the National Command Authority has resulted in the armed services becoming more integrated with each other in preparation for deployment as a US joint force. In addition, US forces are routinely integrated with coalition forces producing a single integrated international force. The Joint National Training Capability (JNTC) under the direction of the Joint Forces Command (JFCOM) is tasked to prepare US forces by providing command staffs and units with an integrated live, virtual, and constructive training environment that includes appropriate joint context, and allows global training and mission rehearsal in support of specific operational needs. JNTCs fundamental principles include:

- Provide for realistic joint exercises against aggressive, free playing opposing forces, with credible feedback
- Provide for an integrated live, virtual, and constructive environment linked to real world C2 systems
- Provide increased realism
- Modernize range infrastructure while allowing new capabilities at minimal risk

The P5 Combat Training System (P5 CTS) is an integral piece of the early JNTC range modernization roadmap that includes an initial operational capability in 2006. The P5CTS program, contract awarded in June 2003, is an "off-the-shelf" non-developmental item (NDI) acquisition with follow-on spiral development upgrades to implement evolving range interoperability standardization. Figure 3 depicts the P5 CTS.

P5 CTS TENA Capability

The P5 CTS is in the process of fielding a TENA gateway within the P5 CTS ground system to further P5 interoperability with T&T ranges.

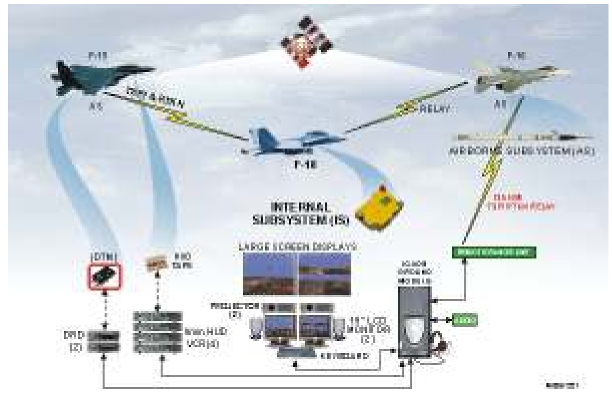

Figure 3. P5 Combat Training System (MS061221)

Cubic Defense Applications (CDA), P5 CTS developer, is participating in the TENA AMT process to define the P5 CTS object model utilizing standard TENA data objects. The P5 CTS TENA gateway will bring P5 CTS closer to realizing the JNTC vision of an interoperable, L-V-C capable training system.

ENHANCED RANGE APPLICATION PROGRAM (EnRAP)

The primary goal of EnRAP is to provide T&E Time-Space-Position Information (TSPI) truth source instrumentation to support advanced aircraft, avionics, and weapons system testing. The EnRAP development effort included significant enhancements in five major areas to meet the needs of the T&E range users.

- Enhanced data transfer flexibility, control, and transmission capabilities including increased data capacity with a spectrally efficient datalink,
- Increased TSPI accuracy and faster data update rates,
- Component miniaturization and modularity for better internal mounting flexibility,
- Standardization of interface protocols and an open architecture design to support flexibility,
- Enhanced system encryption capability with new encryption technology

To obtain the challenging technical requirements of EnRAP; revolutionary, not evolutionary development was required. Multiple simultaneous cutting-edge development efforts were necessary to create a new performance standard for test instrumentation. However, recent cost escalation within the EnRAP program significantly strained the funding available causing the program to be delayed while the program is restructured. In the mean time, existing Advanced Range Application System (ARDS) test range instrumentation will continue to be utilized by the test community until a solution to the EnRAP requirements can be fielded.

EnRAP/ARDS TENA Capability

The EnRAP ground subsystem was required to achieve TENA Extended Compliance (Level 2), by conforming to the rules set forth in the TENA 2002 Architecture Reference Document. All EnRAP range resource applications, including the display and datalink Ground Subsystems, were required to use the standard Application Programming Interface defined by TENA Middleware. An ARDS TENA capability is available today at test ranges. However, it is achieved through a TENA-to-Range gateway where TENA messages are converted to ARDS protocols.

DISTRIBUTED MISSION OPERATIONS (DMO)

Distributed Mission Operations is critical to Air Force readiness and is the cornerstone of Air Force training transformation in accordance with OSD-directed Joint National Training Capability Initiatives. Combat Air Force (CAF) DMO is the foundation for revolutionizing training for the USAF. CAF DMO training systems are comprised of high fidelity man-in-the-loop virtual cockpits for pilots, and C2ISR crew stations. These systems are complemented with training aids which include manned threat stations, instructor-operator stations, computer generated forces implementations, and Brief/De-brief solutions. The Deployment schedule for these Mission Training Centers (MTCs) is illustrated in Figure 4. The CAF DMO training systems support both inter-team and intra-team composite force training for warfighters located in geographically separate locations. Mirroring current doctrine, the CAF DMO System provides warfighters the ability to train as a team, while supporting the enhancement of individual proficiency. The focus is on the operational and strategic training of the warfighter.

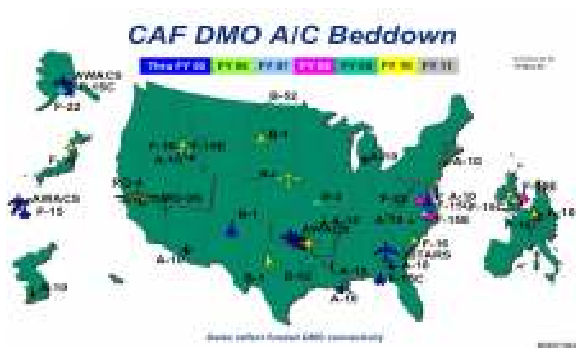

Figure 4. CAF DMO Beddown (MS061094)

Training is accomplished using Mission Training Centers (MTCs) that are connected by the DMO System Network (DMON); a Wide Area Network (WAN). Within the WAN, a Virtual Private Network (VPN) provides connectivity between the sites as well as the means for continuous monitoring and control of the DMO System Network 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 O&I personnel to conduct day-to-day operations of the CAF DMO help desk and administers, monitors, and maintains the private DMT 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.

CAF DMO Interoperability Standards

To realize a truly routine, daily training capability, an overarching inter-site interoperability solution in the form of standards was levied by ACC as a CAF DMO requirement. The interoperability standards apply to all Federate Systems participating in CAF DMO events being executed on the DMO Network. Federate system sites participating in CAF DMO events must use federate system assets and processes that comply with effective DMT System standards criteria. 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 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.

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, and allows MTCs with different simulation protocols to interface with each other across the Distributed Mission Operations Network (DMON) (See Figure 5). The benefits provided by the Portal include the translation of different simulation protocols, 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 DMT 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 Federation. 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 (WAN).

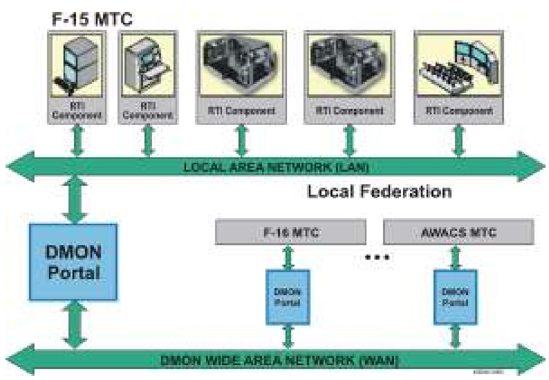

Figure 5. DMON Distributed Mission Operations Network (MS061080)

Figure 6 shows the high-level components of the Portal architecture. MTC data is received at the LAN endpoints which provide a high-performance network interface and 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 Portalese [e.g. Portal – Portal Protocal] 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 Portalese, 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 Portalese 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.

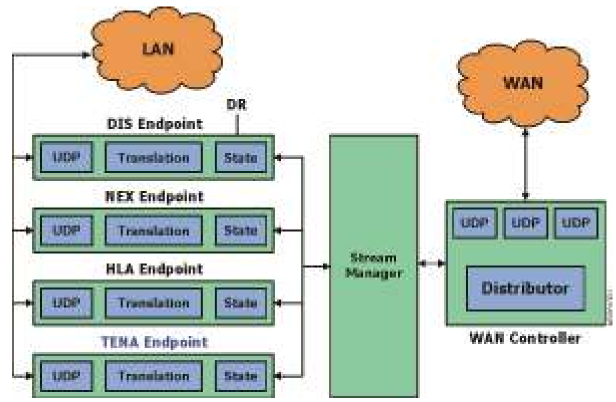

Figure 6. DMON Portal Architecture (MS061081)

ESTABLISHMENT OF L-V-C INTERACTIONS VIA A TENA PORTAL TO THE DISTRIBUTED MISSION TRAINER SYNTHETIC BATTLE SPACE

The standards based CAF DMO architecture has been successfully implemented to provide a routine, global virtual training capability for the warfighter. With the number of CAF DMO training events in excess of 380 per year, the challenge becomes how training capabilities and training assets of Live Ranges can be leveraged to provide a routine DMO L-V-C training capability. Under tasking by ACC, Northrop Grumman is currently defining and implementing 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 will provide an interoperable solution among TENA, HLA, and DIS implementations. This task will provide an initial DMO L-V-C capability and an associated set of candidate standards to govern the DMO L-V-C environment. The four phases of the L-V-C environment are described below.

- Provide a plug and play Live Range audio into the DMO Synthetic Battlespace via a standardized hardware interface.
- Provide an L-V-C entity translation solution. This effort utilized a Cubic TENA v4.1 gateway which translates the live range data into compliant TENA v4.1 objects.
- Introduce DMO Virtual and Constructive entities to Link-16 displays.
- Provide a beyond visual range (BVR) L-V-C provide weapon engagement event including, fly-out, damage assessment, and platform disposition based on L-V-C battlespace data.

The TENA gateway within the DMO Portal has been successfully implemented and has established an L-V-C environment that is being used to meet each phase of the L-V-C environment development. The primary challenges DMO has experienced in creating the L-V-C environment are similar to the disconnections between protocols and differing implementations previously experienced in integrating DMO HLA and DIS architectures. While the representation of live aircraft in the DMO synthetic battlespace provided a high fidelity representation, there are a number of challenges that needed to be overcome. Accessing TENA data for updates is much more onerous than accessing DIS or HLA data. Also, TENA object models do not provide all the information that is required to properly populate HLA and DIS entity fields. Critical platform information such as velocity and acceleration is not available. Another area that impacts L-V-C interoperability solutions are changes to TENA standards defining middleware and Object Models. The upcoming TENA v5.1 upgrade will require substantial Portal modifications to maintain the existing L-V-C solution. The establishment of a standards based L-V-C interoperability solution, which defines acceptable interfaces, data content, and formats, and system performance requirements, would greatly benefit the L-V-C community as a whole.

FUTURE L-V-C CONCEPTS UTILIZING TENA STANDARDS

Although there have been many implementations of L-V-C test and training events in recent years, everyday use of L-V-C concepts remains limited. The problem of L-V-C implementation can be analyzed considering two major communication networks that must be present to connect live, virtual and constructive systems. A wireless network to connect mobile platforms, and a ground based wired network infrastructure. In addition, the data passed throughout these networks to feed simulations providing the virtual and constructive components of L-V-C must be considered.

Airborne Wireless Networks

Basically, there are three major categories of wireless networks capable of providing communication between Test and Training (T&T) instrumented platforms:

- Training systems such as the P5 CTS airborne network.
- Test systems such as ARDS and future EnRAP airborne networks.
- Tactical data link systems such as link 16, Tactical Targeting Network Technology (TTNT), and the developing Joint Tactical Radio Systems' Wideband Networking Waveform (WNW); when used in training scenarios.

All three types of networks are used in some capacity to provide L-V-C capability. Since all three are wireless networks they experience limitations in RF spectrum availability, bandwidth, player capacity, and range compared to ground based networks. All three utilize unique network protocols to transfer as much data as possible given the wireless network limitations discussed above, and all three are continually being improved to deliver greater communication performance.

Ground Based Networks

There are numerous categories of DoD Wide Area Networks (WANs) such as the DMO DMON and JNTC's JTEN. Some wired networks can also be wireless (these wireless networks are usually short-range extensions of wired networks and are considered wired networks in this paper). Wired networks are not usually limited by RF spectrum availability, bandwidth, player capacity, and range. Communication protocols used for wired networks are in general not appropriate for bandwidth constrained, long distance, high data payload because of the amount of data needed to be communicated throughout the network for it to operate, commonly called "network overhead". Network overhead reduces the amount of data that can be transported across the network.

Standard TENA Gateways and Portals Provide an L-V-C Plug and Play Capability

TENA is an excellent starting point for L-V-C interoperability. However, it is not to say that TENA should replace existing wireless and wired communication architectures supporting the virtual domain and current and future tactical data link networks. TENA utilizes a Common Object request Broker Architecture (CORBA) based publish and subscribe mechanism for data exchange among networked applications. TENA's implementation of an execution manager process enables multiple collaborating applications to share a common object model for the purpose of exchanging data and making remote requests. However, the overhead associated with TENA interoperability via network data exchange is large when compared to other communication architectures such as DMOs use of Distributed Interactive Simulation (DIS) or HLA, or the P5 CTS airborne data link protocols that communicate via the broadcast of standardized messages. Useful tenants of the TENA architecture can be adopted without implementing the TENA communication middleware standard across networks such as the DMON and P5 CTS. TENA network interfaces to these systems, commonly called gateways or portals (e.g. DMO Portal) have been established to translate TENA standard data objects into non-TENA data distributed by other network architectures. However, the gateways /portals (translations) from TENA data objects to other data representations (DMO architecture standards in the case of DMON) are not captured under the TENA umbrella. Table 3 lists the TENA tenants that, if used to manage gateways/portals, would lead to an efficient approach for establishing and maintaining plug and play capability between DMO networks and T&T ranges.

Figure 7 illustrates L-V-C interactions through linked wireless and wired networks utilizing TENA gateways/portals as “interoperability glue”. Maintaining standardized gateways/portals to translate TENA data objects from Test and Training wireless networks to DMO networks and using common simulations across live and virtual domains is a first step toward standardized L-V-C plug and play capability.

Table 3. TENA Tenants for Gateway/Portals

TENA Tenant	Implementation	Suggested Activity
Meaningful Communication	Standard Translations from TENA Objects to other data representations	Capture TENA Object Model translations and establish TENA repository
Common Context	Common Understanding of the Environment	Establish standard translations from TENA SEDRIS Object Model to other environments
Meaningful Time	Common understanding of Time	Establish standard translations from TENA Object Model Time to other representations of time.
Technical Process	Use of the TENA AMT	Establish a TENA AMT Process to coordinate updates to gateways/portals

Gateways and portals must however be managed to keep up with changes made on both sides of the gateway/portal. The TENA infrastructure for maintaining middleware would make a good forum for

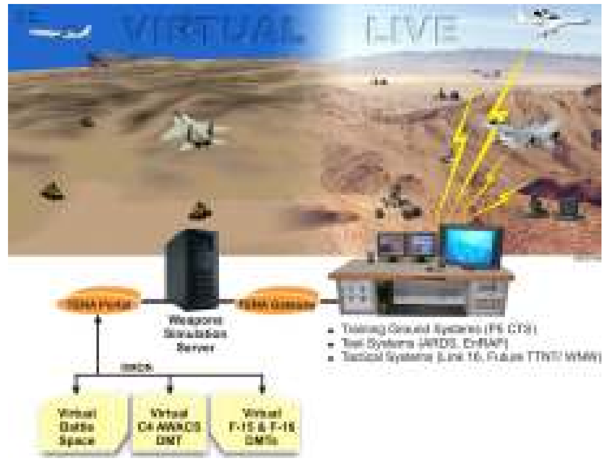

Figure 7. L-V-C Interoperability via TENA Gateways (MS061059)

managing gateways and portals. The TENA object model repository would also be a good candidate for storing reusable, standardized, gateways and portals.

L-V-C Data and Common Weapon Simulations

For meaningful communication to occur between L-V-C systems, a common language is necessary along with common simulations for weapon events. Each user of the L-V-C system must be provided with consistent weapon system results, varying results from simulations of the same weapon because of differences in fidelity of the simulations used will certainly cast doubt on the effectives of the L-V-C system by the T&T using community. For example, a Beyond Visual Range (BVR) AMRAAM missile simulation used in the DMO synthetic battle space should yield the same results as a similar BVR AMRAAM simulation from a live range. In addition, the simulation results should be consistent with platform cockpit representations of weapon launch zones and post launch weapon indications, such as the ZAP models implemented on the F-15, F/A-18E&F, F-16, and planned for the F-35. Therefore, the sharing of common data and common weapon simulations are imperative for robust L-V-C interactions.

TENA Object Models

The TENA AMT continues to introduce standard TENA data objects that are used as building blocks for larger object models (OM) built to support various Test and Training users. The JNTC OM, Navy Tactical Training Range (TTR) OM, Live Training Range OM (P5 Program), all extend the basic TENA objects into OMs supporting the various user needs. The next release of TENA middleware, version 6.0, will include OM subsetting making it easier for TENA standard data objects to be included in larger user specific OMs.

Standard TENA gateways/portals would document and provide middleware that translates the TENA standard objects into other communication architectures.

TENA Interface to P5 CTS Weapon Simulations

In 2005, the First Ann Arbor Corporation (FAAC) (developer of P5 CTS Weapon Simulations) completed the initial phase of an effort to implement a TENA interface to P5 CTS weapon simulations. FAAC successfully demonstrated a distributed weapon simulation capability via a weapon simulation server interfaced to a TENA network. This demonstration moves forward the feasibility of a DMO virtual entity initiating a P5 weapon simulation against a live entity operating within the P5 wireless network. A P5 TENA gateway to the DMO DMON network that includes the exchange of common standardized weapons simulation data would be necessary. Since the FAAC weapon simulations for P5 CTS are based on ZAP weapon launch zone software currently residing in the F-15, F-16, F-18, and planned for the F-35, this TENA implemented distributed weapon simulation capability could provide for a common set of weapon simulation SW across live platform cockpit launch zone solutions, live P5 entities, and virtual DMO entities. The possibility of implementing a common and consistent set of weapon simulations supporting live platform cockpit launch zone indications, virtual entities, and live range platforms is of significant value to the T&T community in assuring a fair and consistent fight between live and virtual players.

Aircraft Mechanization for L-V-C

The Navy F-18 aircraft operational flight program (OFP) has for years supported the computer generated threat system (CGTS) associated with Navy TACTS ranges.

The threat signatures of simulated surface to air threats are uplinked via training instrumentation to the F-18 and used to stimulate the aircraft radar warning receiver (RWR) providing the aircrew indications of a constructive ground threats.

The F-35 plans to incorporate similar embedded training capability. Standardized gateways could provide the connectivity required for virtual ground threats and virtual aircraft platforms to be sensed by live aircraft via stimulation of the live aircraft sensors/RWR via T&T instrumentation leading to robust L-V-C interactions.

SUMMARY

The TENA architecture is an excellent forum to initiate the standardization of interoperability standards which encompass data formats and content, gateway implementations, system interfaces, and object models of networks used to link live test and training ranges with the DMO virtual domain, tactical data links, and a network common weapon simulation server to establish plug and play L-V-C capability. Standards that define the translation activity and middleware necessary to share data across the P5 Combat Training System, current ARDS test ranges, future EnRAP test ranges, tactical data links, and the DMO virtual battle space would lead to a robust, routinely available L-V-C capability. Using a TENA based network server to host P5 CTS distributed weapon simulations would make common weapon simulations available to test range live players and DMO virtual entities resulting in consistent L-V-C simulated weapon engagements.

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