The Test and Training Enabling Architecture (TENA) Enabling Technology for the Joint Mission Environment Test Capability (JMETC) in Live, Virtual, and Constructive (LVC) Environments

By

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ABSTRACT

The Joint Mission Environment Test Capability (JMETC) is a distributed live, virtual, and constructive (LVC) testing capability developed to support the acquisition community and to demonstrate Net-Ready Key Performance Parameters (KPP) requirements in a customer-specific Joint Mission Environment (JME). JMETC, using the Test and Training Enabling Architecture (TENA), provides connectivity to the Services' distributed test capabilities and simulations, and Industry test resources. TENA is well-designed for supporting JMETC events through its architecture and software capabilities which enable interoperability among range instrumentation systems, facilities, and simulations. TENA, used in major exercises and distributed test events, is also interfacing with other emerging range systems.

KEY WORDS

TENA, JMETC, interoperability, resource reuse

INTRODUCTION

Due to the necessity of the continuous evolution of the warfighter, equipment, and concepts being deployed in support of missions around the globe, the United States Department of Defense (DoD) developed geographically dispersed ranges on which to conduct crucial test and training events. The test and training events carried out at these facilities are varied in nature and range anywhere from individual systems under test via small-unit maneuvering, to large-scale Joint Services exercises spread across numerous ranges where LVC systems are blended to enact representative scenarios. While highly capable, these DoD ranges were initially developed with "stovepipe" systems, individually built with different suites of sensors, networks, hardware and software. The focus is now shifting to allow the most efficient use of current and future range resources via range resource integration. This integration fosters interoperability and reuse within the test and training communities, critical to validate weapon system performance, such as the Future Combat System (FCS) or the Joint Strike Fighter (JSF), in a more cost-effective manner.

Being successful in the development of any Joint testing capability requires a supporting and guiding activity, and in December 2005, the JMETC program element was formed. JMETC, the DoD corporate approach for linking distributed facilities with an LVC testing capability, and provides readily available connectivity to the Services' distributed test capabilities and simulations, as well as Industry test resources. Although a testing capability, JMETC is also aligned with and complemented by the Joint National Training Capability (JNTC) integration solutions to foster test, training, and experimental collaboration. The JMETC program employs TENA to prototype new testing support infrastructure. TENA provides JMETC a technology already deployed in DoD by making real-time software system interoperability available via interfaces to existing range assets, simulations, and Command Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) systems.

TENA provides the middleware software component while the JMETC Virtual Private Network (VPN) provides hardware connectivity through utilization of the existing Secure Defense Research and Engineering Network (SDREN) infrastructure. Based on the customer's needs and the potential for reuse, dedicated and trusted connectivity is provided on the SDREN, which is part of the Global Information Grid (GIG). The VPN sites, encrypted for Secret, also include numerous sites at Defense industrial facilities. This infrastructure can be connected to the JNTC-sponsored Network Aggregator to further increase the VPN capability by bridging to sites on other classified networks; to include the JNTC Joint Training and Experimentation Network (JTEN), Defense Information System Network (DISN) networks, the Air Force Integrated Collaborative Environment (AF-ICE) enclave, and potentially other classified enclaves. Together, TENA and JMETC enable and enhance distributed testing and training, as well as range integration. Upgrading an existing range system to TENA is achieved within a few days, drastically shorter than traditional software integration efforts. Additional benefits include cost-effective replacement of unique range protocols, enhanced exchange of mission data, and organic TENA-compliant capabilities at test sites, which can be leveraged for future events.

JMETC VPN operational testing uses the IVT and TENA. Operational testing is performed by the User Support Team to verify the network can operationally support TENA and/or other data protocols. The testing is conducted after the network infrastructure test have been successfully performed by the JMETC network system control and will ensure the backbone JMETC VPN network (Service Delivery Point to Service Delivery Point) and the end-user site network infrastructures are configured for proper and efficient TENA operations. The operational testing is executed in two phases: Phase 1: one-on-one with each new or updated JMETC VPN site, Phase 2: full mesh with all sites to participate in a particular event/exercise.

The JMETC Team's network goal is to complete a VPN infrastructure of 44 connected nodes during 2009. See Figure 1.

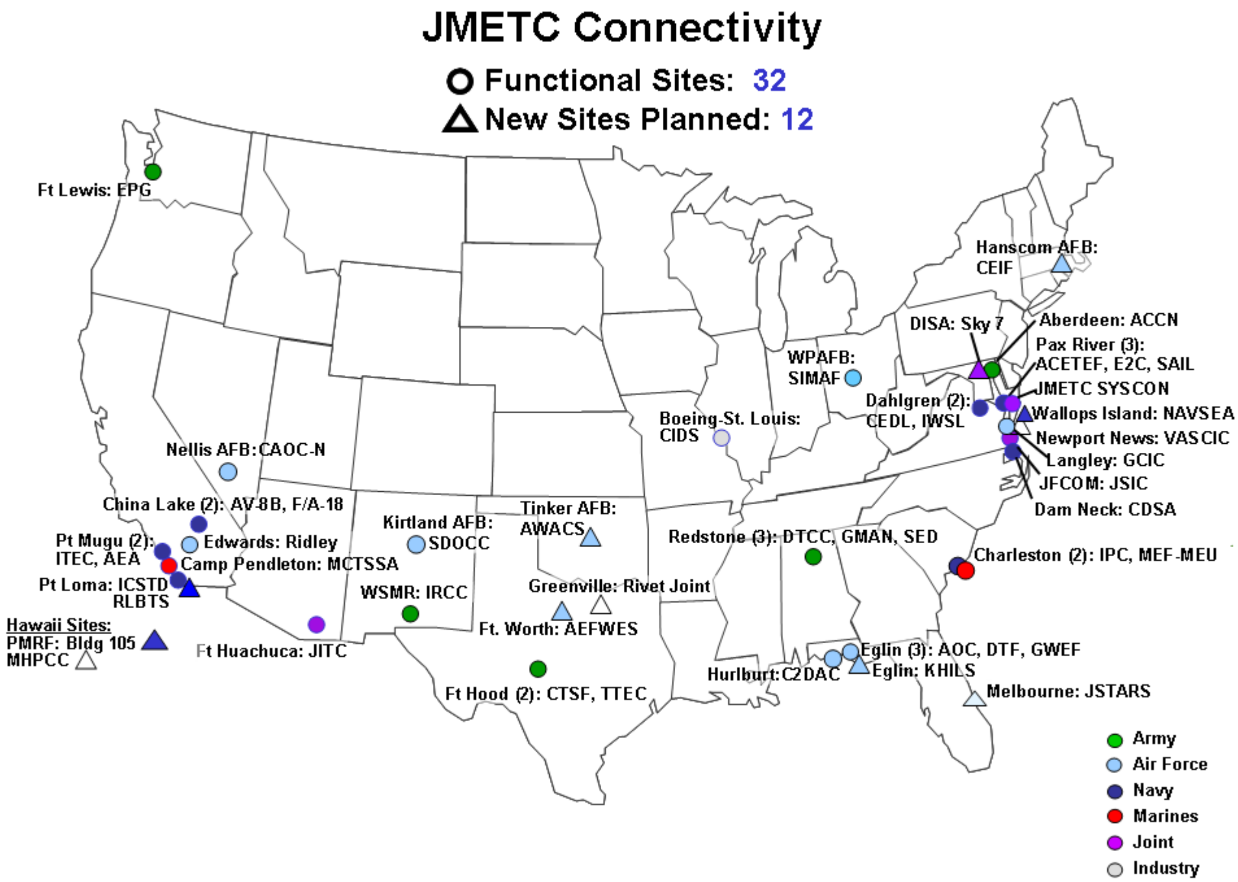

Figure 1. FY09 JMETC VPN

Together, the TENA and JMETC complement enables and enhances distributed testing and training. JMETC is a relatively new presence for the test and training community. Its "stand-up" event was Integral Fire 07 (IF07), an AF-ICE event, which was a distributed test event involving all the military services and the United States (US) Joint Forces Command (JFCOM). TENA has evolved since the late 1990s when it was brought into play to solve an old problem that restricted range effectiveness, allowing for taking advantage of the growth in modeling and simulation and its revolutionary application to training. These concepts were being forwarded in the late 1990s by the Foundation Initiative 2010 (FI 2010) project, sponsored by the Office of the Secretary of Defense (OSD) Central Test and Evaluation Investment Program (CTEIP).

TENA has been field-proven in numerous major field exercises and distributed test events since 2002. The Pacific Alaska Range Complex (PARC), the largest instrumented air, ground, and electronic combat training range in the world, has integrated its systems to include TENA Middleware in order to support its operational mission and requirements. Utilizing TENA, JMETC enabled several initial prototype demonstrations: an Air Combat example (a Data Link Messages Test Environment), Technical Alignment with JNTC events (test and training collaboration), a Land Combat example (FCS test environment), and an Information Operations (IO) example (IO Range integration). JMETC has supported the Joint C4ISR Interoperability Test and Evaluation Capability (InterTEC) project spirals, the goal of which is to present an integrated test solution for scalable, extensible, and operationally relevant interoperability test and evaluation.

The LVC infrastructure provided by JMETC in the US Army's FCS Joint Battlespace Dynamic Deconfliction (JBD2) Event allowed for the successful execution of mission tasks supported by the US Army (USA), Air Force (USAF), Marine Corps (USMC), Navy (USN) and JFCOM. Persistent Fire (PF) 09-01 was conducted over the JMETC VPN using TENA, as was the recent Joint Expeditionary Force Experiment (JEFX) 09-2.

Integral Fire 07 (IF07)

IF07, an AF-ICE event, was a distributed test event involving all the military services to include JFCOM. JMETC supported the event by providing test infrastructure and technical support.

Administered by the Simulation and Analysis Facility (SIMAF) at Wright-Patterson Air Force Base, Ohio, IF07 had three distinct customers: JFCOM's Joint Systems Interoperability Command (JSIC), the DoD Joint Test and Evaluation Methodology (JTEM) Joint Test & Evaluation (JT&E) program, and the Warplan-Warfighter Forwarder (WWF) initiative, sponsored by the USAF Command and Control Intelligence, Surveillance and Reconnaissance (C2ISR) Battle-lab.

For IF07, JMETC created a single infrastructure that served these three distinct customers with different requirements who were able to test independently in the same time frame, thereby making multiple use of the same infrastructure.

JFCOM's JSIC conducted a technical assessment of the digital capability and interoperability to conduct Joint Close Air Support (JCAS) in response to immediate requests.

The JTEM JT&E led a test activity exercising their methods and processes while also providing insight to the Army's Non-line of Sight Launch System/Precision Attack Missile (NLOS/PAM) and Air Force's Network Enabled Weapon (NEW) emerging weapons concepts.

The USAF WWF initiative tested NEW Command and Control concepts leveraging the Joint Air-to-Surface Standoff Missile-Extended Range (JASSM-ER) weapons system. Specifically, WWF assessed machine-to-machine data transfer from the Air Operations Center (AOC) to an airborne platform and then direct to NEW.

TENA was successfully used to exchange simulation or instrumentation data between sites. Specifically within their laboratories, nine sites used the Distributed Interactive Simulation (DIS) Protocol. At each of these local DIS sites, data was converted to TENA using the TENA-DIS Gateway device prior to the data being sent to another site, mitigating configuration challenges of using DIS over wide-area networks. These TENA-DIS Gateways operated satisfactory and all test objectives were met during the Integral Fire 07 test event.

Interoperability Test and Evaluation Capability (InterTEC)

The Joint C4ISR InterTEC Project is an integrated test solution for scalable, extensible, and operationally relevant interoperability test and evaluation and is using TENA in its employment. The performance objective of InterTEC is to field an accredited test system for the conduct of joint interoperability certification testing that integrates existing interoperability testing tools and adds new capabilities in accordance with DoD policy for joint and service interoperability and net readiness assessments of C4ISR networks-of-systems.

The first spiral focused on developing and fielding an accredited, integrated C4ISR interoperability test capability for the tactical data link protocols of the Joint Data Network

(Variable Message Format--VMF, Link 11, and Link 16). In the JMETC prototype event, InterTEC demonstrated extensibility and reuse through the rapid integration of an additional live range environment including live aircraft from the Air Force Flight Test Center at Edwards AFB, California, a virtual F-15E from Eglin AFB, Florida, and additional constructive entities generated from the Air Combat Environment Test & Evaluation Facility (ACETEF) at Patuxent River, Maryland. These sites were combined with existing Spiral 1 sites to perform a joint air combat event in July 2006, and constituted the InterTEC Initial Operational Capability (IOC). Using InterTEC in the JMETC event provided a significant capability addition to InterTEC. Both the Navy Sea Range and Air Force Flight Test Center were able to perform Joint Interoperability testing between Navy and Air Force live entities in a distributed Joint LVC battlespace environment. TENA acted as the key enabler of the reuse demonstration.

Spiral 2, completed in mid-September 2008, extended the capability of Spiral 1 to include an integrated test capability for the Joint Planning Network protocols, to include United States Message Text Formatting (USMTF) and Over The Horizon Targeting-Gold (OTH-G). Spiral 3 will focus on intelligence, surveillance, and reconnaissance systems/protocols, as well as supporting the test processes associated with the Net-Ready KPP.

Pacific Alaska Range Complex (PARC)

PARC, the largest instrumented air, ground, and electronic combat training range in the world, has integrated their systems to include TENA Middleware to support the operational mission and requirements of Red Flag – Alaska (RF-A). PARC is conditionally Accredited and Certified (A&C) as a JNTC venue and is the first live training range within USAF to receive JNTC A&C.

PARC's emphasis is on Joint and Coalition warfighting capabilities, training the warfighter and providing near real experience of first 8-10 combat sorties. Three to four joint and coalition force exercises are executed per year. Each warfighter exercise is a two week joint air and ground war including relevant, real-world combat scenarios with realistic threats and targets. For combat sorties, PARC provides realistic integrated air defense threats, target arrays, and adversaries, providing realistic and relevant scenarios that also improve Joint and Coalition interoperability. Training venues supported include:

- RF-A exercises;
- Northern Edge (NE) – Pacific Command (PACOM)-sponsored, theater-wide;
- JEFX; as well as
- Unit level training – Distant Frontier.

Many platforms have trained at PARC, including fighters, bombers, tankers, C2, ground, and C4ISR. Training missions include Air-to-Air (A2A), Air-to-Ground (ATG), Offensive Counter Air (OCA), Defensive Counter Air (DCA), Close Air Support (CAS), and Electronic Warfare (EW), as well as Personnel Recovery/Combat Search and Rescue (PR/CSAR), insertion/extraction, special ops, and tactical airlift.

Essentially PARC has created a black TENA network and red TENA network. Systems on either side publish and subscribe TENA objects and messages as needed/required; SimShield provides multi-level security as a cross domain solution by allowing these two networks to communicate seamlessly at near real time.

Joint Battlespace Dynamic Deconfliction (JBD2)

In August 2008, JMETC provided LVC infrastructure support to the US Army's FCS JBD2 Event. This was a complex distributed Joint test using the JMETC infrastructure and technical support which successfully connected 16 sites and 40 unique LVC systems in four time zones.

The complexity and success of the LVC infrastructure provided by JMETC in JBD2 allowed for the execution and free play of 6 unique Joint Fires and JCAS key mission tasks supported by the US Army, Air Force, Marine Corps, Navy, and JFCOM.

With multiple customers, JBD2 was designed to establish a rigorous test context to examine Army FCS test technology requirements needed for testing in a Joint environment. Using the test tools supplied by InterTEC, as well as TENA-transported data, the JMETC VPN was able to provide gateways so other architectures could communicate and provide data into the JBD2 scenario. Supported by JMETC, the JBD2 Test Event provided a valuable risk reduction for critical FCS test technology areas, critical network test technologies and distributed test infrastructure technologies. JBD2 also allowed the JMETC network infrastructure to further develop the baseline capability needed to support system of systems level of testing across the Services.

The JMETC VPN performed superbly in this high profile and high data density event. The use of the JMETC and InterTEC tools and JMETC infrastructure, as well as the JMETC on-site and Help Desk customer support, were instrumental in allowing the very complex JBD2 Test Event to meet or exceed all test objectives.

Persistent Fire 09-01 (PF09-01)

JMETC also participated in the planning and execution of Persistent Fire 09-01 (PF09-01) which was a distributed LVC event stressing interoperability among systems and was intended to assess initiatives in support of immediate Digital Close Air Support (DCAS) and NEW. The event was conducted over the JMETC VPN and used TENA.

The main sites were SIMAF Wright Paterson Air Force Base (AFB), Global Cyberspace Integration Center (GCIC) Langley AFB, and Command Control Test Facility – Datalink Test Facility (C2TF–DTF) Eglin AFB. Supporting sites were Systems Control (SYSCON) Pax River, Distributed Test Control Center (DTCC) Huntsville, and Guided Weapons Evaluation Facility (GWEF) Eglin AFB. TENA gateways were employed at the sites to convert DIS data from the facilities to TENA. Reuse of TENA-DIS gateways from the JBD2 event was very successful with no changes required to the gateways. Training of event personnel in TENA operations and other infrastructure tasks was successful. The event was conducted with essentially minimal assistance from the TENA/JMETC team.

Joint Expeditionary Force Experiment (JEFX) 09-01 and 09-2/3

Most recently, JMETC was involved in JEFX 09-01 and 09-2/3, a series of experiments that combined LVC forces to assess the ability of selected initiatives to provide needed capabilities to warfighters. The focus was on live fly communication and airborne data links. The event was scheduled for Feb-April 2009 and was conducted over the JMETC VPN. The JFCOM JNTC Aggregation Router was used for connection to the VIP briefing facility in the Pentagon, the Warfighter Capability Demonstration Center (WARCAP) through the AF-ICE network. The main sites were the Combined Air Operations Center (CAOC-N) Nellis AFB, 505th Command

and Control Wing (CCW) Hurlburt Field (also a training venue), both of which were recently funded by the users to install the VPN. Also included were Electronic Systems Command (ESC) Hanscom AFB, SIMAF Wright-Patterson AFB, GCIC Langley AFB, GWEF Eglin AFB, and C2TF – DTF Eglin AFB. Supporting sites were JMETC SYSCON Pax River and DTCC Huntsville. The TENA Team provided TENA-DIS gateways to sites for simulation data and live fly data.

TENA OFFERS INTEROPERABILITY AND RESOURCE REUSE

Interoperability is the characteristic of an independently developed software element that enables it to work together with other elements toward a common goal. Interoperability focuses on what is common among software elements. Reuse is the ability to use a software element in a context for which it was not originally designed, so reuse focuses on the multiple uses of a single element and requires well-documented interfaces. To achieve interoperability, a common architecture, an ability to meaningfully communicate (including a common language and a common communication mechanism), and a common context (including the environment and time) must be present. To bring the efficiency and economic advantages of interoperability and reuse to the DoD test and training ranges, FI 2010 developed TENA. The FI 2010 program completed the initial interoperability and reuse efforts in early Fiscal Year 2005, and the continuing interoperability and reuse refinement of TENA is now managed by the TENA Software Development Activity (SDA).

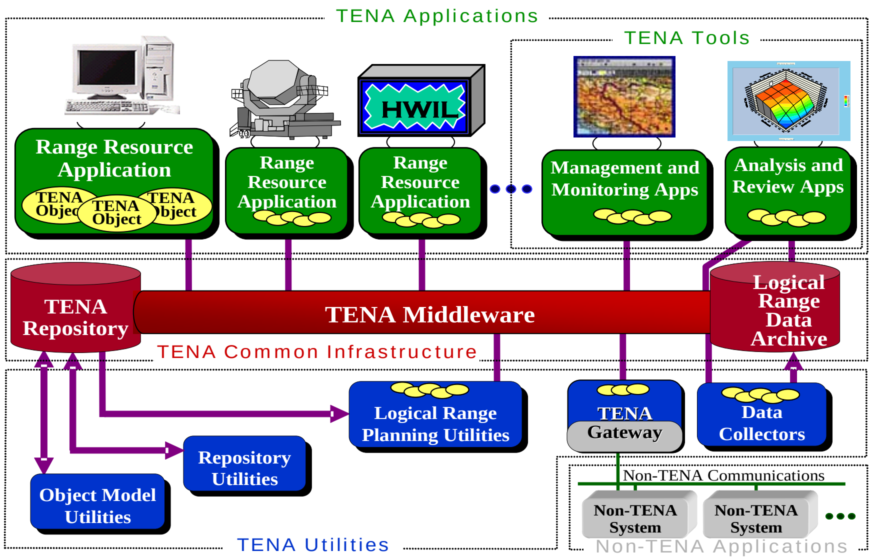

Figure 2. TENA Architecture Overview

The TENA architecture is a technical blueprint for achieving an interoperable, 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, some simulated—that can be rapidly combined to meet new testing and training missions in a realistic manner. Please refer to Figure 2. TENA is made up of several components, including a domain-specific object model that supports information transfer throughout the event lifecycle, common real-time and non-real-time software infrastructures for manipulating objects, as well as standards, protocols, rules, supporting software, and other key components.

The TENA Middleware combines distributed shared memory, anonymous publish-subscribe, and model-driven distributed object-oriented programming paradigms into a single distributed middleware system. This unique combination of high-level programming abstractions yields a powerful middleware system that enables the middleware users to rapidly develop complex yet reliable distributed applications. The TENA Middleware, US Government owned and available for free download at the TENA SDA web site https://www.tena-sda.com, is currently at Release 5.2.2. Beta versions of Release 6 are available for download.

The TENA object model consists of those object/data definitions, derived from range instrumentation or other sources, which are used in a given execution to meet the immediate needs and requirements of a specific user for a specific range event. The object model is shared by all TENA resource applications in an execution. It may contain elements of the standard TENA object model although it is not required to do so. Each execution is semantically bound together by its object model.

Therefore, defining an object model for a particular execution is the most important task to be performed to integrate the separate range resource applications into a single event. In order to support the formal definition of TENA object models, a standard metamodel has been developed to specify the modeling constructs that are supported by TENA. This model is formally specified by the XML Metadata Interchange standard and can be represented by Universal Markup Language. Standards for representing metamodels are being developed under the Object Management Group Model Driven Architecture activities. The TENA Object Model Compiler is based on the formal representation of this metamodel, and TENA user-submitted object models are verified against the metamodel. However, it is important to recognize the difference between the TENA metamodel and a particular TENA object model. The object captures the formal definition of the particular object/data elements that are shared between TENA applications participating in a particular execution while the object model is constrained by the features supported by the metamodel.

A significant benefit for TENA users is auto-code generation. The TENA Middleware is designed to enable the rapid development of distributed applications that exchange data using the publish-subscribe paradigm. While many publish-subscribe systems exist, few possess the high-level programming abstractions presented by the TENA Middleware. The TENA Middleware provides these high-level abstractions by using auto-code generation to create a complex Common Object Request Broker Architecture (CORBA) application. As such, the TENA Middleware offers programming abstractions not present in CORBA and provides a strongly-type-checked framework interface that is much less error-prone than the existing CORBA API. These higher-level programming abstractions combined with a framework designed to reduce programming errors enable users quickly and correctly to express the concepts of their applications. Re-usable standardized object interfaces and implementations further simplify the application development process.

Through the use of auto code generation, other utilities, and a growing number of common tools, TENA also provides an enhanced capability to accomplish the routine tasks which are performed on the test and training ranges in support of exercises. The steps in many of the tasks are automated, and the information flow is streamlined between tools and the common infrastructure components through the enhanced software interoperability provided by TENA. TENA utilities facilitate the creation of TENA-compliant software and the installing, integrating, and testing of the software at each designated range. This complex task falls to the Logical Range Developer, which, in this phase, performs the detailed activities described in the requirement definitions and event planning, and the event construction, setup, and rehearsal activities of the Logical Range Concept of Operations. While some manual exercise and event setup is required at ranges, TENA tools, as they are developed and become accepted across the range community, will make exercise pre-event management easier.

EMERGING RANGE SYSTEMS AND THE USE OF TENA

TENA's field proven capabilities are being used by other emerging range systems, including the Integrated Network Enhanced Telemetry (iNET) program which provides a solution to capture greater efficiencies in the use of spectrum through revolutionary changes in how flight tests are conducted. TENA is enabling a demonstration prototype to investigate the use of TENA across a constrained environment simulating iNET capabilities. In the process of creating this demonstration, key resource requirements imposed by pairing TENA with iNET for current and anticipated future flight hardware (e.g. size, power, memory, bandwidth) can be measured and/or predicted. Further, creating the demonstration will provide an environment for experimenting with the use of TENA for meeting iNET Metadata requirements. It is expected that performing and documenting this effort will provide guidance to future science and technology topics for iNET and TENA. Other systems or events using or planning to use JMETC/TENA include the Technology for Tactical Video (TTV), the Integrated Architecture Behavior Model (IABM) in the Single Integrated Air Picture (SIAP) Joint Combined Hardware-in-the-Loop Evaluation Phase 5 (JCHE5), and Unmanned Aerial Systems in National Airspace (UAS in NAS), Live-Virtual-Constructive-Development Distributed Environment for the Broad Area Maritime Surveillance (LVC-DE BAMS).

TENA SUPPORT FOR TENA USERS

TENA SDA has developed a highly utilitarian website that provides a wide range of support for the TENA user, including an easy process to download the middleware which is free. The website also offers a help desk and user forums that will address any problems with the middleware download and implementation. TENA SDA is very aware of the need to inform range managers and train TENA users, and the TENA SDA presents regular training classes that are designed to meet the attendees' needs from an overview of TENA to a technical introduction to TENA to a hands-on, computer lab class for the TENA Middleware.

TENA's continuing evolution in its support of the test and training ranges community is managed by an organization of users and developers. This collection of TENA stakeholders, called the Architecture Management Team, meets every six or eight weeks to be updated on TENA usage, problems, and advancements. The agenda involves briefings and open and wide ranging discussions, and it ensures the users' concerns and inputs are understood, recorded, and made action items, if necessary. Of no less importance, TENA developers and management has had a long and mutually beneficial relationship with the Range Commanders Council.

CONCLUSION

Although it was a technological and software evolution that was the impetus for TENA's growth in its enabling of range interoperability and resource reuse, the middleware found its needed validation on the DoD test and training ranges. On those ranges, the US Military evaluates the warfighting equipment, personnel, and concepts that are deployed in support of the ongoing missions around the globe. Exercises, experiments, and demonstrations are the stages for the evaluation, but it is the data collection and analysis that determines the war worthiness of the equipment or concept under test. Now paired with JMETC to prove connectivity as well as interoperability and reuse, TENA is being accepted as an important part of the equation.

However, events only provide the opportunity for evaluation. It is the data collection and analysis that determines the war worthiness of the equipment or concept under test; it can quickly and definitively illuminate any necessary improvements needed to ensure effective and safe weapon system operation and training. JMETC and TENA reduce the cost and time to plan and prepare for distributed joint events by providing a readily-available, persistent connectivity, common integration software for linking sites, and test tools; putting the focus back on the event itself, invariably affecting almost every aspect of range operation and management, including budget definition and approval.

For more information, please visit the JMETC or TENA web sites: http://www.jmetc.org or http://www.tena-sda.org.