TENA AND JMRTC, ENABLING INTEGRATED TESTING IN JOINT DISTRIBUTED LVC ENVIRONMENTS

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Abstract— The TENA SDA has developed and validated a common architecture called TENA, which provides for real-time software system interoperability using the TENA Middleware, as well as interfaces to existing range assets, C4ISR systems, and simulations. The TENA Middleware, currently at Release 6.0.3, has been used by the range community for testing, evaluation, and feedback in many major exercises since 2002 and has been selected as the interoperability solution in JMRTC’s distributed testing. Through investment in TRMC’s T&E/S&T Program and innovative use by Pacific Missile Range Facility (PMRF) and White Sands Missile Range (WSMR), TENA is expanding to the Telemetry community.

I. 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 to large-scale Joint exercises spread across numerous ranges where live, virtual, and constructive (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 making interoperability difficult. 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 F-35 Joint Strike Fighter (JSF), in a more cost-effective manner.

The Test and Training Enabling Architecture (TENA) is the DoD corporate approach for interoperability of distributed range facilities with an LVC capability. This includes the Services as well as Industry resources. TENA provides real-time software system interoperability by interfacing to existing live range assets, plus Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) systems, and simulations.

TENA provides the middleware software component and can be used on any Internet Protocol Based network such as the Joint Mission Environment Test Capability (JMRTC) Network as well as the Joint Staff (JS) J7 Joint and Coalition Warfare (JCW) Joint Training and Experimentation Network (JTEN). TENA enables and enhances distributed testing and training, as well as range integration. Upgrading an existing range system to TENA can be achieved in drastically shorter time 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 sites, which can be leveraged for future events, enhancing both re-use and interoperability.
II. THE TELEMETRY COMMUNITY AND TENA

A. TENA in Resource Constrained Environments (TRCE)

The rapid growth in Net-Centric warfare, coupled with the increasing need for interoperability among test ranges and sites, has led to a great diversity in the DoD testing infrastructure and the networks supporting it. The primary challenge of enabling interoperability for systems under test in a mission-level context in a distributed LVC dynamic Joint Net-Centric Operations (JNO) environment is being met by adopting TENA. For TENA to service the entire mission area, it must be able to function in this diverse, resource-constrained environment. Therefore, the OSD Test Resource Management Center (TRMC) Test and Evaluation (T&E) / Science and Technology (S&T) Program is sponsoring the TENA in Resource Constrained Environments (TRCE) approach. TRCE will improve the TENA Middleware’s operation and performance in resource-constrained environments by developing technologies that support a broad range of variable quality networks, including wireless networks, and provide native TENA support for handheld & embedded computing platforms. TRCE will enhance the TENA Middleware to support these types of networks and platforms to provide a common and robust interoperability architecture.

The TRCE project is focused on developing capabilities to extend the use of the TENA Middleware to remote and potentially tactical edge instrumentation and systems under test. Two key aspects of the program focus on developing reliable communication with performance constrained links (related to variable quality and low data rate networks) and operation on constrained hardware devices (related to low power, reduced CPU and reduced memory). Examples of constrained link types may be wireless, cellular, acoustic, SATCOM, and other RF communications. Furthermore, hardware constraints exist in the form of low power & small form factor computers, embedded instrumentation, and mobile internet devices (MID) such as computers on module, smartphones, and tablet computers. This variability and unpredictability in the overall test environment presents significant challenges in achieving interoperability; TRCE technologies are being developed in order improve the reliability and robustness of the TENA middleware in these types of environments.

B. TENA Software Decommutation System (TSDS)

The TENA Software Decommutation System (TSDS) leverages code generation technologies to increase flexibility and interoperability when processing telemetry data. TSDS implements TENA within the decommutation process in order to bring TENA as close as possible to the data source and reduce system latency associated with data translation. TSDS provides code generated software decommutation for flexible and agile processing of telemetry data. Bit synchronization and frame synchronization are performed before data is sent to TSDS, using hardware from any number of vendors, and TSDS takes as an input a time tagged minor frame encapsulated within a packet. There are three attributes of TSDS that make it of interest to the broader T&E community.

- TSDS offers a native TENA interface so that telemetry data can be published directly into TENA object models.
- TSDS is a software based approach to telemetry stream decommutation implemented within Java. TSDS runs on standard personal computer (PC) hardware.
- TSDS leverages auto code generation technologies to reduce the effort associated with updating decommutation systems to support new telemetry stream definitions. The use of
code generation in software decommutation offers potential cost savings throughout the entire T&E community.

In order to provide the flexibility required to handle a variety of telemetry streams, TSDS is implemented with a modular architecture comprising 4 major components. This modularity offers the following benefits. It:

- Takes advantage of modern multi-processor and multi-core computers, thus maximizing the supported flow of telemetry data;
- Supports multiple ways in which raw telemetry data frames are collected;
- Allows publication of selected telemetry data to TENA;
- Simplifies the porting to different platforms; and
- Facilitates the automatic generation of the components themselves.

C. Joint Test and Training Operations Control Capability (JTTOCC)

The purpose of the Joint Test and Training Operations Control Capability (JTTOCC) is to increase mission throughput to support Joint test and training missions across cooperatively linked air, land and sea ranges. Current requirements on the Major Range and Test Facility Bases (MRTFBs) as well as the demands of multi-service test and training require increased Command and Control (C2) to maintain test and training safety. JTTOCC will enhance the capability of the current test and training command and control systems in the following areas: Synchronized mission planning and collaborative scheduling; Enhanced real-time range command and control; and Post-mission data capture, analysis, reporting and archival capabilities. The JTTOCC incorporates an open architecture design for potential use at any MRTFB; hence it is using TENA to provide interfaces to the major functional components. TENA cross-domain software enables web viewers to provide a real-time Common Operating Picture (COP) that is either at the UNCLASSIFIED or SECRET level. The design strategy for this effort concept involves a ‘closed-loop’ system, comprised of three process areas – Collaborative Scheduling, Real-time Operations and Post-Mission Analysis. Collaborative inputs from user scheduling systems result in a final schedule or official Operations Order (OPORD). This OPORD is used within the C2 Center for real-time operations on the day of concurrent test and training missions to map scheduled missions to missions being executed. This linkage, along with range data sources and data feeds, is displayed in a Common Operating Picture. Range users create tailorable views of the COP to enhance situational awareness and allow mission flexibility.

Together, the TENA and JMECT complement enables and enhances distributed testing and training. While JMECT is a relatively new presence for the test and training community, TENA has evolved since the late 1990s when it was brought into play to solve an old problem that restricted range effectiveness. Many of the early range data collection and analysis systems were part of a vertical “stovepipe” growth of the instrumentation and instrumentation suites, and not able to utilize the advantages found in the concepts of range interoperability and range resource reuse. These concepts allowed for taking easy advantage of the growth in modeling and simulation and its revolutionary application to training, 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).
III. RECENT AND ONGOING TEST AND TRAINING EVENTS INVOLVING THE UNITED STATES MILITARY USING JMTC/TENA

A. Pacific Alaska Range Complex (PARC)

Pacific Alaska Range Complex (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 Joint Red Flag – Alaska (JRF-A). PARC is conditionally Accredited and Certified (A&C) as a JNTC venue and is the first live training range 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:

- JRF-A exercises;
- Northern Edge (NE) – Pacific Command (PACOM) sponsored, theater-wide;
- Joint Expeditionary Force Experiment (JEFX);
- 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, air-to-ground, Offensive Counter Air (OCA), Defensive Counter Air (DCA), Close Air Support (CAS), Electronic Warfare (EW), Suppression of Enemy Air Defense (SEAD), and Active Array Radar (AAR), as well as Personnel Recovery (PR)/Combat Search and Recovery (CSAR), insertion/extraction, special ops, and tactical airlift.

Essentially PARC has created both 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.

B. Interoperability Test and Evaluation Capability (InterTEC)

The Joint C4ISR Interoperability Test and Evaluation Capability (InterTEC) 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 Service interoperability and net readiness assessments of C4ISR networks-of-systems.

InterTEC is currently involved in its Cyber Event (ICE) execution. The specific goal of ICE is to continue developing and institutionalizing architecture to support T&E requirements for combining LVC and Information Operations (IO) activities for Information Assurance (IA) / Computer Network Defense (CND) testing. The Threat Systems Management Office (TSMO) at Redstone Arsenal, Huntsville, AL will be conducting operations during ICE. The Joint Information Operations Range (JIOR) network will have a limited connection to the SDREN at Eglin AFB 46TS AOC facility to enable actions from TSMO.
C. Range Radar Replacement Program (RRRP)

PEO STRI Range Radar Replacement Program (RRRP) has selected TENA for the interface to all future ARMY Range Time Space Positioning Information (TSPI) Radars. The TENA Software Development Activity (SDA) is working with RRRP on a TENA Radar Track and Radar System Data set for these new radars. The Range Commander Council Electronic Trajectory Measurements Group (ETMG) Radar Subcommittee has a task to adopt the Radar data definitions for all service range radar interfaces. The TENA SDA has also developed a TENA pointing data set for the RRRP programs to provide pointing data to all other range TSPI Instrumentation. Radars will be purchased under RRRP for all Army Test Centers to include: White Sands Missile Range (WSMR), Yuma Proving Grounds (YPG), Redstone Test Center (RTC), and Aberdeen Test Center (ATC).

D. Coalition Attack Guidance Experiment (CAGE)

As TENA has been chosen for the over-the-wire transport protocol for CAGE II, Team members continue to support integration spirals. The Coalition Attack Guidance Experiment (CAGE) is a series of experiments designed to examine and evolve The Technical Cooperation Program (TTCP) members’ abilities to conduct collaborative Research and Development (R&D) in the areas of battlespace management technologies and processes for dynamic mission execution, resource allocation and enhanced collaboration airspace deconfliction and integration. CAGE II is expected to execute Runs for Record (RFR) in November 2012. Sites include JMETC participants RTC, Eglin AFB and Hanscom AFB as well as Coalition location in Canada (Canadian Forces Warfare Center at Shirleys Bay in Ottawa) and Australia (Joint Battle Lab in Canberra).

E. Air Ground Integrated Layer Exploration (AGILE) Fire

AGILE Fire is an AF-ICE event providing an LVC environment designed to actively support the Secretary of the Air Force Chief of Warfighting Integration Modeling and Simulation investment for maturing existing data links, as well as emerging command and control capabilities; focus on the interoperability within and between air and ground communication layers; and to capture requirements for emerging technologies and interfaces to existing force structure.

Both the AGILE Fire Phase I and II events leveraged the persistent JMETC infrastructure to integrate facilities, labs and resources. Fourteen sites were involved in the events including one new site: Northrop Grumman Corporation B-2 Aircraft Lab, El Segundo, CA, brought up on short notice.

Phase III of the Event was executed in the first quarter of FY11, the purpose of which was to identify interoperability gaps, shortfalls, and overlaps with current systems and networks supporting Joint Fires within and between the United States Air Force and Army air / ground communication layers. Specifically, AGILE Fire III was meant to conduct technical and operational assessments of the information exchange requirements and interoperability in order to support conventional mission threads to include Joint Close Air Support (JCAS) and Surface/Indirect Fires, as well as advanced data links combat operations in a denied access area. Fifteen sites were involved in the events including a new site: Fire Support Engineering Division (FSED), Ft Sill, OK, was brought up on short notice.

Phase IV of the Event was executed in the fourth quarter of FY11, the purpose of which was on exploring system interoperability, integration procedures and information exchange requirements within and between space, air and ground domains to execute operational realistic mission threads. The focus was largely on CAS and Airspace de-confliction and management involving
data links, emerging C2 capabilities, requirements for emerging technologies, interfaces to existing force structure in mission contexts, and to support participating technologies’ analytical objectives. TENA was used for simulation and truth data at all 10 participating sites.

JMETC tools were used extensively, such as TENA gateways for data transfer among sites, InterTEC tools for data link analysis, the IVT to check-out and verify the operation of both JMETC connectivity and TENA applications, and Voice over Internet Protocol (VoIP). Of particular note was the first time use of JMETC chat services for event team collaboration, and Secure File Transfer Protocol (SFTP) services for file transfer; both very successfully.

Phase V of the Event was executed in the first quarter of FY12, the purpose of which was to support the Joint Fires, Integrated Air and Missile Defense and Air Interdiction mission threads. Of particular note was the first time use of JMETC Adobe Connect services for Time Ordered Event List services and event team collaboration. Thirteen sites were involved in the events including two new sites: Georgia Tech Research Institute (GTRI), Atlanta, GA, and Joint Deployable Analysis Team (JDAT), Eglin AFB, FL. GTRI is JMETC’s first academia site.

JMETC met the infrastructure requirements of AGILE Fire. The event team was very pleased with the infrastructure and technical support provided by JMETC. They reported they were able to collect significant data of value to the warfighter concerning their specific objectives. The event team also strongly felt the AGILE Fire event reaffirmed the value of distributed testing.

IV. TENA OFFERS INTEROPERABILITY AND RESOURCE REUSE

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, is a distributed LVC testing capability developed to support the acquisition community during program development, developmental testing, operational testing, interoperability certification, including demonstration of Net Ready Key Performance Parameters (KPP) requirements in a customer-specific Joint Mission Environment (JME). JMETC 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 Joint National Training Capability (JNTC) integration solutions to foster test, training, and experimental collaboration.

The JMETC program has used TENA to build a new testing support infrastructure. TENA, as the live range instrumentation architecture for test organizations and JNTC, and field-proven in major field exercises as well as numerous distributed test events since 2002, provides JMETC a technology already deployed in the DoD. TENA provides the middleware and software component while the persistent JMETC network provides the hardware connectivity. This is accomplished through the utilization of the existing Secure Defense Research and Engineering Network (SDREN) and Defense Research and Engineering Network (DREN) infrastructure.

Interoperability is the characteristic of an independently developed software element that enables it to work together with other elements toward a common goal by focusing on what is common among them. Reuse is the ability to use a software element in a context for which it was not originally designed, in essence focusing on the multiple uses of a single element and often requiring well-documented interfaces. In order 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).

The TENA architecture is a technical blueprint for achieving an interoperable, composable set (composability 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. 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 (currently at Release 6.0.3) is US Government owned and available for free download at the TENA SDA web site [https://www.tena-sda.com](https://www.tena-sda.com).

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 Extensible Markup Language (XML) Metadata Interchange standard and can be represented by Universal Markup Language (UML). 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.
Application Programming Interface (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.

V. SUPPORT FOR TENA USERS

The TENA SDA has developed a website that provides a wide range of support for the TENA user, including an easy process to download the middleware, free of charge. The website also offers a help desk and user forums that will address any problems with the Middleware download and implementation. The 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 of TENA, all the way 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 (AMT), several times a year to be updated on TENA usage, problems, and advancements. The agenda involves briefings and open wide ranging discussions, ensuring the users’ concerns and inputs are understood, recorded, and action items are made if necessary. Of equal importance, TENA developers and management has had a long and mutually beneficial relationship with the Range Commanders Council.

VI. 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 U.S. Military evaluates the warfighting equipment, personnel, and concepts that are deployed in support of the ongoing missions around the globe. 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; it can quickly and definitively illuminate any necessary improvements needed to ensure effective and safe weapon system operation and training. Now paired with JMETC to prove connectivity as well as interoperability and reuse, TENA is commonly accepted as an integral part of the
equation. TENA and JMETC reduce the cost and time to plan and prepare for distributed Joint events by providing a readily-available, common integration software for linking sites, plus test tools; putting the focus back on the event itself.

For more information about JMETC and TENA, contact George Rumford, JMETC Senior Technical Advisor / TENA SDA Director, or AJ Pathmanathan, JMETC Systems Engineer, E-mail: feedback@jmetc.org or feedback@tena-sda.org or go to the JMETC Web Site: https://www.jmetc.org or TENA Web Site: https://www.tena-sda.org.