# THE CTEIP TEST AND TRAINING ENABLING ARCHITECTURE, TENA, AN IMPORTANT COMPONENT IN REALIZING DOD TEST AND TRAINING RANGE INTEROPERABILITY


## ABSTRACT

While military asset testing and training might be seen as complementary in supporting military prepareness, they cannot complement each other without an effective and efficient method of distributing data laterally across geographically separated data gathering, analysis, and display systems. This cost-effective integration of range data and telemetry resources is critical to ensuring the war worthiness of today's advanced weapon systems such as the Joint Strike Fighter and the sensor and weapon platforms such as the highly sophisticated unmanned vehicles that are beginning to populate the air, land, and sea areas of operations. To ensure the advantages of range interoperability are available across the DoD Test and Training ranges, a Central Test and Evaluation Program (CTEIP) project has developed and is refining the Test and Training Enabling Architecture (TENA).

The core of TENA is the TENA Common Infrastructure, including the TENA Middleware and TENA Repository. The TENA Middleware is the high-performance, real-time, low-latency communication infrastructure used by range instrumentation software and tools during execution of a range event. The TENA Object Model enables semantic interoperability among range resource applications by encoding the information to be communicated among those range applications. It may be seen as a range community-wide set of interface and protocol definitions encapsulated in an object-oriented design. The TENA tools, utilities, and gateways assist the user in creating and managing an integration of range resources, as well as in optimizing the TENA Common Infrastructure.

TENA has proven to be a critical enabler of distributed live exercises to include the U.S. Joint Forces Command's Millennium Challenge 2002, two major Joint National Training Capability exercises in 2004, Cope Thunder 04-02, and Joint Roving Sands/Red Flag 2005. TENA, as integral part of range data systems, has become an important component in the realization of range interoperability.



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## TENA PROVIDES BLUEPRINT FOR RANGE INTEROPERABILITY AND RESOURCE REUSE

The United States Department of Defense (DoD) has invested millions of dollars in test, training, and evaluation ranges. Geographically dispersed, spread from the Atlantic to the Pacific and from the Canadian border to the Mexican border and including Hawaii, Alaska, and the United States territories, the air, land, and sea ranges are used by the U.S. Military Services and various other agencies with training and equipment needs that must be resolved and validated at these ranges. As these DoD ranges expanded in mission types and acquired resources, each range tended to develop "vertically," each building on 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).

Range interoperability requires the use of a common architecture (including a common language, communication mechanism and context [including the environment and time]) to meaningfully communicate across divergent systems, and range resource reuse requires well-documented system interfaces that ensure commonality. Refer to Figure 1. FI 2010's Test and Training Enabling Architecture (TENA) 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, some simulated—that can be rapidly combined to meet new testing and training missions in a realistic manner. The FI 2010 project is closing, and sustainment of TENA will be under the guidance of the TENA Software Development Activity (SDA), a Defense Test Resource Management Center (DTRMC) CTEIP Office and the U.S. Joint Forces Command (USJFCOM) Joint National Training Capability (JNTC) Program Management Office.

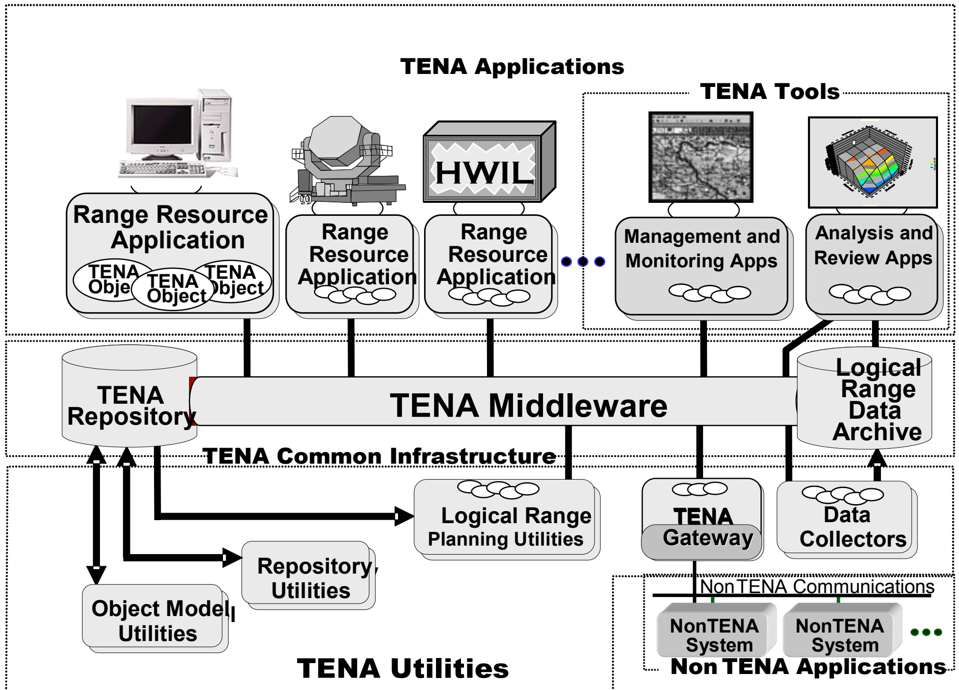


**Figure 1. TENA Architecture Overview.**

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. Within the TENA concept, a common Logical Range Object Model (LROM) is defined as being linked into all interoperating applications on the network. This object model defines the TENA objects that are available for any participating application to either publish (send), subscribe (receive), or both. It is the definition of the object model and the use of common middleware data distribution that enables interoperability. Each interoperating application may translate from the TENA object model formats to local data representations as required.

The integrated environment, created by integrating testing, training, simulation, and high-performance computing technologies which can be distributed across many facilities, is called a "logical range." In a logical range, real military assets, such as ships, aircraft, and ground vehicles, can interact with each other and with simulated weapons and forces, no matter where these forces, real or simulated, actually exist throughout the world. Further defined, a logical range is a range without geographic boundaries. An instance of the logical range is created at a point in time when specific customer requirements dictate a need for interoperability, sharing, or reuse of resources. Resources or assets may include platforms, instrumentation, software modules, test or training exercise plans or data products, models, simulators, air or water space, computers and stimulators. The logical range meets customer requirements when it creates a dynamic entity that schedules and integrates resources, plans, executes, and delivers a customer data package. It allows facilities and test or training ranges to expand their capabilities and provide more comprehensive resources and services assembled to meet customer requirements." TENA's operational driving requirements focus on supporting a logical range throughout the entire range event lifecycle, supporting testing and training in a network-centric warfare environment, supporting rapid application and logical range development, supporting integration with modeling and simulation, supporting a wide variety of range systems, and supporting the gradual deployment of TENA onto the ranges and usage in military exercises.

## MILITARY EXERCISES UTILIZE TENA'S INTEROPERABILITY AND REUSE CAPABILITIES

Millennium Challenge 2002 (MC02) was the first major exercise to make use of the TENA approach to interoperability and reuse. The USJFCOM exercise, held 23 July through 9 August 2002, was a joint experiment, transformation event, and major field exercise. The exercise was designed to test some of the then current USJFCOM key strategic concepts and capabilities and to concentrate on the future concepts and capabilities of the U.S. Army, U.S. Navy, U.S. Marine Corps, U.S. Air Force, and the Special Operations Command. This look at current and future concepts and capabilities also extended to the data-gathering and data-distribution networks used throughout the range community for testing and training and in particular, the concepts and capabilities of range interoperability and resource reuse. TENA was chosen as the data-distribution system enabler for the exercise's live-events.

USJFCOM and a MC02 Western Range consortium of participating ranges developed a range integration package which supported the then USJFCOM Commander's intent that "…the live portion of the event will…demonstrate the ability to link existing ranges within a joint event…". This goal was accomplished by extracting live-force participants' track and status data at the instrumented data fusion points at each range and delivering the data to TENA software gateways which "standardized" the various range data formats. The standardized data was then distributed over the MC02 Range Integration network to the Joint Training, Analysis, and Simulations Center and other event locations, where the live data was fused with the model federation picture. Also included in the original intent for MC02 was the need to provide a seamless "ground truth" picture of the combined live and virtual joint forces participating in the event. Accomplishment of the MC02 goals depended largely on a data distribution system capable of seamlessly linking the various data points, requirements that even at that early stage of TENA development were well within the range of TENA capabilities.

The MC02 Range Integration effort shared time-space-position information (TSPI) data between the ranges involved in the project. This data were distributed in a common format and represented on a common range display such that it was transparent to the casual viewer that the data was coming from several different sites across the country.

Any editing/smoothing was left as a range-specific function, trying to remain as close as possible to "range ground truth". This effort integrated TSPI data from the following range facilities: Land Range (LR) and Electronic Combat Range (ECR) at NAVAIR, China Lake, California; Sea Range (SR) at NAVAIR, Pt. Mugu, California; National Training Center (NTC) at Fort Irwin, California; Nellis AFB, Nevada; Southern California Logistics Airport (SCLA); and Southern California Offshore Range (SCORE) with the simulated environment of the MC02 project. Each range sent, received, displayed, filtered, and logged the data using the gateway approach with a custom user interface and a common display picture.

The MC02 implementation concept was to build a core piece of software with as many common features as possible based on the TENA Middleware framework using a common MC02 object model. Two legacy range applications were adapted to use the TENA prototype middleware for MC02: the TSPI Internal Entity Re-formatter (TIER) and the RangeView display. The applications provided range system interfaces, local data format translations, and display capabilities. TEIR was adapted to use TENA as "Gateways" – translating range information from the legacy application format to the TENA objects, while RangeView compiled the TENA Middleware for a technically superior "native" application. As the TIER and RangeView applications progressed, it was determined that TIER would implement the unique range data systems interfaces, and that RangeView would provide additional display and analysis capabilities.

As the conduit for Ground Truth TSPI data from the Ranges to Command and Control Systems at USJFCOM, TENA successfully met the test objectives for each of the exercise rehearsals and during the MC02 execution, worked reliably for days without failure.

In January 2004, the USJFCOM Joint National Training Capability (JNTC) conducted a the Western Range Complex Horizontal Training Event. This large scale exercise spread its personnel and equipment and its data gathering and distribution networks from the Fort Irwin and Twenty-Nine Palms ranges in California to the USJFCOM location in Suffolk, Virginia, with exercise and data points in Nevada, New Mexico, Kansas, Alabama, Florida, and Georgia. Hundreds of air sorties and days of ground maneuvering played out the scenario as exercise data flowed from various disparate instrumentation systems. TENA connected these individually distinct systems and the geographically separated ranges and allowed a smooth data flow to TENA-enabled displays and data analysis points. Live air and ground tracks from the NTC, Nellis AFB, and Twentynine Palms ranges were integrated and distributed to USJFCOM to create a Live, Virtual, and Constructive (LVC) Joint training environment. See Figure 2. Resource reuse was demonstrated with the utilization of the data displays, Rangeview and the Personal Computer Debriefing System (PCDS).

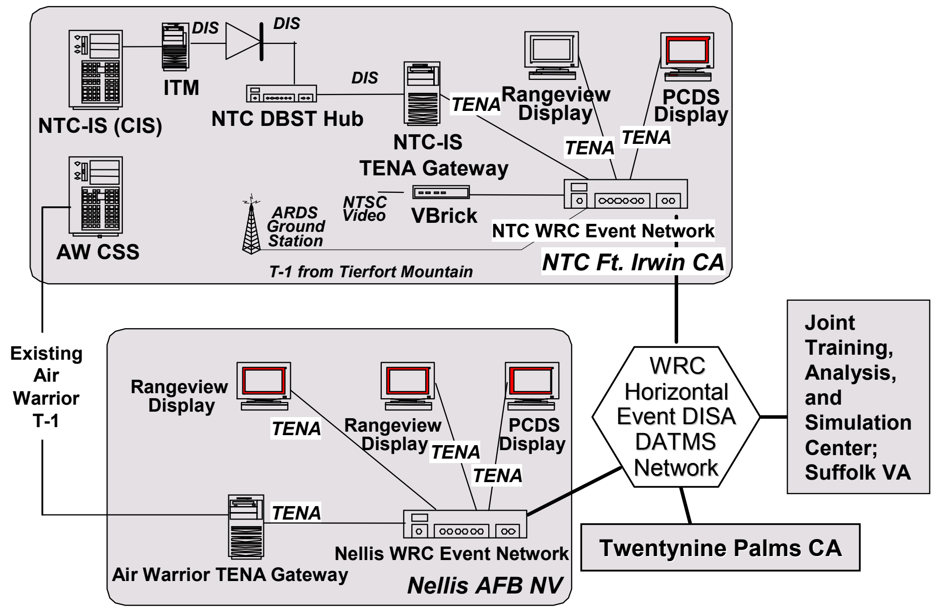


**Figure 2. Western Range Complex Integration and Instrumentation Solution.**

TENA was also used in the follow-on JNTC June 2004 event, an integrated training event, known as CJTFEX 04-2 (Combined Joint Task Force Exercise 04-2) or Operation Blinding Storm. The exercise was held mostly on the East Coast, building a Joint training exercise atop a planned U.S. Navy 2nd Fleet training event. The exercise encompassed both "horizontal" (tactical) as well as "vertical" (command staff) training and included 28,000 coalition service personnel from Army, Navy, Marine, and Air Force units in Maryland, Virginia, North Carolina, South Carolina, and Florida. The exercise was the largest JNTC event usage of TENA to date, integrating both test and training range instrumentation systems. A TENA to High Level Architecture (HLA) gateway capability provided the live data to an HLA-based simulation federation. The RTCA system, used in previous exercises, used data provided through TENA interfaces.

TENA-enabled resources in the JNTC January and June events included the following live range instrumentation systems, analysis and display systems, and live-to-simulation gateway systems:

- Advanced Range Data System (ARDS and ARDS-Lite) instrumentation interface
- Army National Training Center Instrumentation System (NTC-IS) instrumentation interface
- United States Air Force Air Warrior instrumentation interface
- United States Marine Corps Integrated Global Positioning System Radio System (IGRS) instrumentation interface
- Large Area Tracking Range (LATR) system
- GALAXY A LATR-type system used by the United Kingdom

- United States Navy Naval Air Systems Command (NAVAIR) RangeView analysis system and display
- NAVAIR After Action Review AAR/Monitor Display (Personal Computer Debriefing System - PCDS)
- Joint Close Air Support Joint Test & Evaluation COMBAT analysis system and display
- Patriot Program Office, Tactical Office (TACO) analysis and display system
- Army Test and Evaluation Command, engagement adjudication workstation ( "Common Data Link – CDL") (Also MSI)
- JNTC Live-to-Simulation gateway TENA to High Level Architecture application named GOTH
- Warfare Assessment Model (WAM) system
- Time, Space, Position Information (TSPI) Internal Entity Re-formatter (TIER)
- Joint Tactical Information Distribution System named RAT TRAP
- Automated Deep Operation Coordination System (ADOCS)
- TENA to Distributed Interactive Simulation (DIS) analysis system named TOSTADA
- Static Target Generator (STG)
- SureTrak Airspace radar monitoring system

TENA's capability to maximize reuse in other events, for example, the JNTC Logical Range Object Model, was used to implement TENA gateways in the Cope Thunder 04-02 exercise held in Alaska in August 2004. Cope Thunder, conducted up to four times a year, is a multi-service, multi-platform, realistic combat operations exercise.

At the behest of their Pacific Air Force (PACAF) customer, Cubic Defense Applications, the defense segment of Cubic Corporation, executed a plan to use TENA to combine real-time data from U.S. Air Force and U.S. Army Test and Training systems for display and recording on a common display. ARDS was used in addition to the the following Air Force and Army systems:

- Deployable System for Training and readiness (DSTARS)
- Aircraft Combat Training System (ACTS) Instrumentation
- Coarse Acquisition Code Receiver (CACR)

The exercise utilized Elmendorf Air Force Base (AFB) for air-to air training and the Eielson AFB Yukon range for air-to-air, air-to-ground, and Electronic Warfare (EW) training; the two ranges are parts of the large Pacific Alaskan Range Complex (PARC). Prior to the exercise, a Central Computer System (CCS)/TENA gateway was developed to support the high-activity, low-activity, threat and ground player messages that were integrated into the Tactical Aircrew Combat Training System (TACTS) / Maneuvering Instrumentation (ACMI) range CCS network at Eielson AFB and Elmendorf AFB.

TENA gateways were developed at the two bases for a TENA-compatible Individual Combat Aircrew Debriefing Subsystem (ICADS), converting the existing Eielson and Elmendorf CCS Display and Debriefing Subsystem (DDS) interface to a TENA compliant architecture. The TENA gateway converted and combined standard CCS/ICADS message traffic from the ranges into a TENA compliant data stream. The TENA ICADS also accepted and processed TENA objects and displayed combined Yukon Measurement and Debriefing System and Stony Military Operations Area exercise data including aircraft, ground troops, and EW threats.

TENA was also used extensively in the recent multi-range, joint-service Joint Red Flag 2005 (JRF05) exercise. 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 and combined into a JNTC event. JRF05 involved LVC and was reported as the largest integrated exercise utilizing live and virtual simulations to date.

The live instrumentation portion of the exercise started March 21 and concluded on April 2, 2005. During the exercise, TENA was used on over 80 computers running over 24 different data gathering, display, and analysis applications linking Nellis Air Force Base, Nevada; White Sands Missile Range, New Mexico; Fort Bliss, Texas; the Joint Exercise Control Group (JECG), Hurlburt Field, Florida; and the Joint Training Analysis and Simulation Center (JTASC), Suffolk, Virginia.

Initial indications are that TENA data distribution in Joint Red Flag 2005 was satisfactory. It provided reliable live instrumentation systems data injection into the constructive and virtual event infrastructures and real-time display and analysis of the instrumentation and LINK-16 data.

## SIGNIFICANT TENA BENEFIT FOR USERS

A significant TENA benefit, realized immediately in these exercises, 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 Programmers' Interface (API). These higher-level programming abstractions combined with a framework designed to reduce programming errors enable users to quickly and correctly express the concepts of their applications. Re-usable standardized object interfaces and implementations further simplify the application development process.

## SUPPORT FOR TENA USERS IS EXTENSIVE AND READILY AVAILABLE

TENA SDA has a 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 Middleware, currently at Release 5, can be used across many common platforms, including:

- Fedora Core 3, GCC 3.4.3
- Red Hat Linux 8.0 (2.4.18 kernel), GCC 3.2 and GCC 3.4.3
- Red Hat Linux 9.0 (2.4.20 kernel), GCC 3.2.2
- Sun Solaris™ 8 (SPARC), GCC 3.2.3
- SGI IRIX 6.5. (22m), GCC3.3
- Microsoft Windows® 2000 (Service Pack 4), Microsoft Visual C++ 7.1
- Microsoft Windows® XP (Service Pack 1), Microsoft Visual C++ 7.1

TENA's continuing evolution 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, open, and wide ranging discussions, and it ensures the users' concerns and inputs are understood, recorded, and made action items, if necessary. TENA's evolution owes as much to the users as it does to the developers. 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 U.S. 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. TENA is being accepted as an important part of the equation.