Test and Training Enabling Architecture (TENA) for ITEA Cyber Security Workshop

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TRMC Invests in Live Virtual Constructive (LVC) Infrastructure

TRMC maintains an implemented architecture and network for Red and Blue LVC Test and Evaluation:

- TENA: Mature, continuously improved software architecture (15+ yrs)
- JMETC: Mature, continuously improved network infrastructure (8+ yrs)
- Standard interface definitions for integrating Red and/or Blue systems
  - Proven tools to rapidly integrate and execute LVC tests
  - TRMC subject matter experts to help plan, design, & execute tests
  - Acceptance and pedigree across the services
  - Used to support 186 distributed test events since 2007

All linked via TENA & JMETC
Why TENA?
Range System and Infrastructure Development Challenges

- General Development Challenges
  - Multiple Developers and Development Groups
  - Different Timelines and Delivery Dates
  - New Computing and Communication Technologies

- Range Specific Development Challenges
  - Multiple Sponsors and Funding Sources
  - Evolving Test and Training Requirements
  - Expansion of Inter-Range Connectivity
  - Information Assurance Policies and Procedures
  - Range Modernization Must Be Gradual

Challenges grow exponentially when you need to interoperate with other LVC ranges
Test and Training Enabling Architecture (TENA) at a Glance

TENA is DoD’s GOTS range integration architecture

- What does TENA enable?
  - Interoperability between inter- and intra-range assets
  - Elimination of proprietary interfaces to range instrumentation
  - Efficient incremental upgrades to test and training capabilities
  - Integration of Live, Virtual, and Constructive assets (locally or distributed)
  - Sharing and reuse of common capabilities across existing and new investments

- What is included in the TENA architecture?
  - Customizable “data contracts” that standardize repeatable information exchange
  - Interoperability-enabling, auto-code generated software libraries
  - A core set of tools that address common test and training requirements
  - Collaboration mechanisms that facilitate sharing and reuse

- TENA has a plan for continued evolution and funding to execute this plan
Where TENA is Used

- Any situation where test and training data needs to be passed over Internet Protocol (IP) networks to include:
  - Interfacing two or more systems for information exchange
  - Across programming languages and computing platforms
  - Receiving system health & status information
  - Remote command & control of one or more systems
  - Real-time dissemination of instrumentation data
  - Communicating with web applications & browsers
  - Injecting virtual and/or constructive data with live assets and instrumentation

- TENA is not intended to replace messaging formats used in theater operations
  - Examples: LINK-16, Variable Messaging Format
TENA Information Assurance (IA) Activities

- **Air Force Evaluated/Approved Product List (E/APL)**
  - Approved 11/18/2010, currently preparing test results for TENA Console

- **Navy Application & Database Management System (DADMS)**
  - Approved 6/27/2011

- **Army Certificate of Networthiness (CoN)**
  - Approved 10/8/2013 and covers TENA Software Suite 6.x (including TENA-enabled applications)

- **S/DREN (Secret/Defense Research and Engineering Network)**
  - TENA protocol and TENA-based applications approved for DREN and SDREN sites

- **NIPRnet**
  - JTTOCC (which uses TENA) obtained ATO 12/27/2012

- **DIACAP**
  - InterTEC tool suite (which includes TENA Middleware) currently in DIACAP testing (with AF 46TS)

- **Unified Cross Domain Management Office (UCDMO)**
  - TENA-enabled Cross Domain trusted guard SimShield v2.2.0.1 on baseline list
  - SPAWAR (Charleston) performed Security Analysis of TENA for use in a Cross Domain Solution to support future C&A activities related to CDS systems using TENA

TENA project working with IA organizations to reduce cost and delays with ability to operate TENA applications
Worldwide Use of TENA

TENA is used in 13 countries outside the US
TENA Architecture Overview

TENA Applications
- Non-TENA Applications
- Range Resource Application
  - TENA Object
  - TENA Object
- Range Resource Application
  - TENA Object
- Range Resource Application
- Reusable Applications
- Reusable Applications

TENA Utilities
- Object Model Utilities
- Repository Utilities
- TENA Utilities
- Infrastructure Management and Planning Utilities
- TENA Gateway
- Data Collectors

TENA Tools
- Logical Range Data Archive
- Non-TENA Communications
  - Non-TENA System
  - Non-TENA System

TENA Common Infrastructure
- TENA Middleware
- TENA Repository
TENA is an Open Architecture

- SEI defines an Open System as “a collection of interacting software, hardware, and human components designed to satisfy stated needs with interface specifications of its components that are fully defined, available to the public, maintained according to group consensus, in which the implementations of the components conform to the interface specifications.”

- TENA is maintained according to a consensus of its users assembled as the TENA Architecture Management Team (AMT)
  - TENA Architectural Specification is publicly defined and available on the web
  - TENA Middleware Specification (API) is publicly available on the web
  - TENA Object Model is publicly available and downloadable without restriction
    - An Event Designer can create or modify object models for a given event to satisfy their particular event requirements

- TENA Middleware exists and is being used to support real events
  - Built on open source software – CORBA ACE/TAO
  - Government owned, without proprietary software
  - Studying possible open source release
Current AMT Members:
- 329 Armament Systems Group (329 ARSG)
- Aberdeen Test Center (ATC), Aberdeen Proving Ground, MD
- Air Armament Center (AAC), Eglin AFB, FL
- Air Force Flight Test Center (AFFTC), Edwards AFB, CA
- Alaska Training Range Evolution Plan (ATREP)
- Army Operational Test Command (OTC), Fort Hood, TX
- Common Training Instrumentation Architecture (CTIA)
- Common Range Integrated Instrumentation System (CRIIS)
- Dugway Proving Ground (DPG)
- Electronic Proving Ground (EPG)
- integrated Network Enhanced Telemetry (iNET)
- Interoperability Test and Evaluation Capability (InterTEC)
- Joint Fires Integration & Interoperability Team (JFIIT)
- Joint Mission Environment Test Capability (JMETC)
- Joint National Training Capability (JNTC)
- Naval Air Warfare Center – Aircraft Division
- NAWC – Weapons Division
- Naval Aviation Training Systems Program Office (PMA-205)
- Naval Undersea Warfare Center (NUWC)
- NAVSEA Warfare Center - Keyport
- P5 Combat Training System (P5CTS)
- Pacific Missile Range Facility (PMRF)
- Redstone Test Center (RTC)
- T&E/S&T Non-Intrusive & Advanced Instrumentation
- White Sands Missile Range (WSMR)
- Yuma Proving Ground (YPG)


Industry Advising Members
- Boeing
- Cubic Defense
- DRS
- Embedded Planet
- EMC
- General Dynamics – C4 Systems
- Kenetics
- MAK Technologies
- NetAcquire
- Raytheon
- Science Applications International Corp (SAIC)
- Scientific Research Corporation (SRC)
- Scientific Solutions, Inc. (SSI)
- Trusted Computer Solutions

International Participation
- Australia
- Denmark
- France
- Singapore
- Sweden
- United Kingdom
What Makes TENA Unique?
Core Architectural Tenets

- **Promote Computer Enforceable System Interfaces**
  - For meaningful interoperability, systems should formally define their interfaces for the particular data produced or consumed and the services/algorithms provided or required.
  - Generic interfaces may look appealing, but significant costs exist with performance, interoperability, and maintenance that are overlooked with this perceived flexibility.

- **Utilize Auto-Code Generation to Raise the Abstraction Level**
  - Distributed programming is hard! Define higher level abstractions to automatically generate properly designed and tested source code for common distributed programming solutions—similar to comparison of modern programming languages to assembly code.

- **Let Computer Detect Interoperability Errors as Early as Possible**
  - When would you like to detect interoperability problems? Many system errors can be detected by the computer during the development phase, reducing overall expense.

- **Design the Middleware to Make it Hard to Use Wrong**
  - Middleware is defined from a defensive posture that minimizes the opportunity for improper usage and run-time anomalies.

- **Anticipate Better Techniques and Technologies**
  - Maintain separation between interfaces and implementations to simplify transition to improved techniques and technologies when appropriate.

- **Emphasize Live-Virtual-Constructive Interoperability**
  - Systems don’t have to use TENA Middleware natively in order to take advantage of some of TENA’s capabilities.
TENA Object Models

- Enable semantic interoperability among range resource applications
- Provide the “common language” that all range resource applications use to communicate

Object Model Stages

- **User-Defined Objects** – objects defined solely for the purpose of a given logical range by TENA users
- **TENA Candidate Objects** – objects defined as potential standards, which are undergoing test and evaluation by the community prior to standardization
- **TENA Standard Objects** – objects developed and supported by the TENA SDA, which have been approved for standardization by the AMT
TENA Objects are Compiled In

● Why use compiled-in object definitions?
  ● **Strong type-checking**
    ● Don’t wait until runtime to find errors that a compiler could detect
  ● **Performance**
    ● Interpretation of methods/attributes has significant impact
  ● Ability to easily handle complex object relationships
  ● Conforms to current best software engineering practices

● How do you support compiled-in object definitions?
  ● Use a language like CORBA Interface Definition Language to define object interface and object state structure
  ● Use **code generation** to implement the required functionality

● Thus the concept of the **TENA Definition Language (TDL)** was created
  ● Very similar to IDL and C++
TENA Standard Object Models:
A Common Set of Data Definitions for the Entire Range Community

- **Platform Related**
  - TENA-Platform-v4
  - TENA-PlatformDetails-v4
  - TENA-PlatformType-v2
  - TENA-Embedded-v3
  - TENA-Munition-v3
  - TENA-SyncController-v1
  - TENA-UniqueID-v3

- **Time-Space Position Information (TSPI) Related**
  - TENA-TSPI-v5
  - TENA-Time-v2
  - TENA-SRFserver-v2
  - TENA-Pointing-v1

- **JNTC OMs (for Training)**
  - JNTC-AirRange-v2
  - JNTC-CounterMeasure-v2
  - JNTC-IndirectFire-v2
  - JNTC-Instrumentation-v2
  - JNTC-NBC-v2
  - JNTC-ObstacleMinefield-v2
  - JNTC-Threat-v2

- **Others**
  - TENA-AMO-v2
  - TENA-Engagement-v4
  - TENA-Exercise-v1
  - TENA-GPS-v3
  - TENA-Radar-v3

- **In Progress**
  - Range Instrumentation OM Suite
  - TENA-AVstream
  - TENA-LiftoffDetector
  - TENA-Link16
  - TENA-PowerController
  - TENA-SpectrumAnalyzer
  - TENA-Telemetry
  - TENA-Waypoint
  - TENA-Weather
  - Additional JNTC OMs for training
How TENA is Currently Used Across Test and Training Facilities

- Common specifications for test and training data
- Data Dissemination across variable applications, platforms, programming languages, networks, and classification levels
- Data Collection and Playback
- Local and Remote Command and Control
- Health & Status Monitoring
- Real-Time simulations
- Stimulation of live sensors and instrumentation
- Connecting non-interoperable inter- and intra-range systems
- Eliminating proprietary interfaces to range instrumentation
- Sharing and reuse of common range tools and capabilities
- Online Collaboration and File Sharing

These activities are all relevant to cyber experiments
How TENA Supports T&E: Notional Test Walkthrough

TENA enables efficiencies through inherent interoperability and reuse

1. Test Planning & Requirements Definition
2. Test Design
3. Event Construction, Setup and Rehearsal

Pre-Test

- TENA Repository
- TENA Object Models

Test

- TENA Tools & Utilities
- Test Execution Examples

Post-Test

- Test Execution
- Analysis & Reporting
- TENA Data Collection System
We can leverage “traditional” exercise capabilities in cyber exercises and vice versa
Notional Cyber Simulation Integration with LVC Environment

LVC Environment

Scenario Executes

Entity Status / Events

Cyber Effects

Cyber Model of Environment

<<TENA Objects / Messages>>

<<TENA Local Classes>>

Standard Effect(s)

Cyber Simulation
Summary

- The Test and Training Enabling Architecture (TENA) is helping standardize integration of test systems to enable more efficient T&E
  - Government-owned, community managed software matured over 15+ years of development & real-world use
  - Auto-code generation that streamlines integration and modifications
  - Enables standard, repeatable Live Virtual Constructive (LVC) integration
  - Institutionally resourced for user support, maintenance, and improvements
  - TRMC is investigating how to leverage TENA to support cyber T&E

- TENA provides value to programs conducting T&E
  - Reduced test setup and integration time
  - Government-owned interface to modeling & simulation capabilities
  - Efficient LVC integration
  - Extensive library of applications and source code available for reuse

Specifying use of TENA in the RFP enables benefits to be realized
Important Contact Information

- **Project Website:** [https://www.tena-sda.org/](https://www.tena-sda.org/)
  - Download TENA Middleware: [https://www.tena-sda.org/repository/](https://www.tena-sda.org/repository/)
  - Submit Helpdesk Case: [https://www.tena-sda.org/helpdesk/](https://www.tena-sda.org/helpdesk/)
  - Use for technical questions regarding TENA

- **TENA Feedback:** [feedback@tena-sda.org](mailto:feedback@tena-sda.org)
  - Provide technical feedback on TENA Architecture or Middleware
  - Ask non-technical questions regarding TENA
  - Provide responses to AMT action items
  - Request TENA training
Backup Slides

Example Test Walkthrough
Some Examples of TENA Usage

- InterTEC (C4ISR stim/sim/collection)
- JDAS (data archive)
- TVDS (video distribution)
- JMITS (live range IR threat emulator)
- SIMDIS (range display)
- Starship (event control)
- Gateways (translators to DIS & HLA)
- CTIA (training instrumentation)
- ARDS (precision TSPI)
- CRIIS (next generation precision TSPI)
- P5 (precision TSPI / ACMI)
- NACTS (precision TSPI / ACMI)
- SimShield (trusted data guard)
- Reflect (data playback)
- MatLab (data analysis)
- Execution Manager GUI (event control)
- IVT (interface/network verification tools)
- JAAR (after action review)
- JIMM (constructive simulation)
- JSAF (constructive simulation)
- DCIT (distributed monitoring)
- Link-16 translator (Link-16 over WAN)
- PET (air picture data analysis system)
- JWinWAM (test assessment tool)
- Real-time Casualty Assessment System
- ICADS (individual combat aircrew dis. sys.)
- ATREP (training instrumentation)
- iNET (wireless networking)
- CRS-P (constructive simulation)
- AEA HWIL (airborne electr. attack lab)
- OT-TES (tactical engagement sys for OT)
- ADMAS (embedded vehicle instruments)
- HWIL RF threat injection system
- Radars (tracking, surveillance, miss-distance)
- Range optics (high fidelity remote control)
- Threat systems
- UAV remote control of sensors
- Range safety systems
- Embedded instrumentation
- Weather server (distribution of weather data)
- Player ID server (Unique ID for entities)
- Open air range acoustic sensors
- Undersea hydrophone instrumentation
- Live video – synthetic scene integration
Partial Listing of Recent Testing, Training, and Experiments Using TENA-Compliant Capabilities

● **Test Events**
  - Joint Distributed IRCM Ground-test System (JDIGS), Mar 10-Ongoing
  - Interoperability Test and Evaluation Capability (InterTEC) Cyberspace Event, Nov 11
  - Air-to-Ground Integrated Layer Exploration (AGILE) Fire III, IV, V, Jan-Nov 11
  - Joint Track Manager Concept-Demonstration (JTMC-D), Jun-Sep 11
  - Joint Integration Air & Missile Defense Office (JIAMDO) Joint Sensor Integration (JSI), Apr-Aug 11
  - Air Force Systems Interoperability Test (AFSIT), Jun-Jul 11
  - Joint Strike Fighter (JSF) Test, Jun 11
  - JIAMDO Correlation / Decorrelation Interoperability Test (CDIT) United Kingdom, Oct 10, Mar 11
  - JIAMDO CDIT CONUS, Sep 10-Jan 11
  - JITC Joint Interoperability Test (JIT) of Air Defense Systems, Sep-Nov 10
  - Broad Aerial Maritime Surveillance (BAMS) Test Oct 09 and Oct 10
  - Battlefield Airborne Communications Node (BACN) Joint Urgent Operational Need (JUON), Aug 10
  - B-1B Link-16 Interoperability Testing, Mar-Apr 10
  - Joint Electronic Warfare Assessment for Test and Evaluation, Sep 09

● **Training Exercises**
  - Daily Training, Eielson AFB
  - Daily Training, Fallon AFB
  - Unified Endeavor (UE) 11-3, May-June 11, UE 11-1 Phase 6, Aug-Sep 11
  - Joint Close Air Support (JCAS) Distributed Test, Jun 10
  - Red Flag Alaska (RFA), four times a year since 2008, Pacific Alaska Range Complex (PARC)
  - JDEWR Cope Tiger 09, Mar 09, PARC
  - RFA 09-2, April-May 09, PARC
  - Distant Frontier, May-Jun 09, PARC
  - Northern Edge 09, Jun 09, PARC
  - Talisman Sabre 09 - Australian Army and US Army, Jul 09, Shoalwater Bay, Queensland Australia
  - RFA 09-3, Jul-Aug 09, PARC
  - JDEWR Talisman Sabre 09, Jul 09, PARC
  - RFA 10-1, Oct 09; 10-2, Apr 10; 10-3 Aug 10
  - Northern Edge, Jun 10

● **Experiments**
  - Joint Surface Warfare (JSuW) Joint Capabilities Technology Demonstration (JCTD), Oct 10
  - Joint Expeditionary Force Experiment (JEFX) 09-1, 09-2, 09-3, Feb-Apr 09
  - JEFX 09-4 B-2 Test (Spirit ICE), Aug 09
  - JEFX 10-1, 10-2, 10-3, Jan-Apr 10
Test Planning: TENA Website Services
https://www.tena-sda.org/

- Currently 8,378 user accounts
- 206 separate activity groups
- 16.5 million page hits in 2014
- Helpdesk cases resolved in 2014 was 2,452
- Currently supporting 40 computer platforms
- 1,198 different object models
- Repository software downloads of 2,877 in 2014
- 727 middleware development kits downloaded in 2014
The Goal of the Block 1 MLS-JCNE implementation is to provide the RDT&E community with a persistent, interoperable, and reusable capability to exchange unclassified data between unclassified and classified enclaves.
Test Construction / Setup: TENA Tools

- Tools are applications, components, or utilities required to support a successful test execution.

- The TENA SDA maintains a library of tools that address common test requirements:
  - Common tools enable a consistent depiction of the test environment.
  - All tools and supporting documentation available through the TENA Repository.

- Some example tools include:
  - Collaboration and Sharing: TENA Repository
  - Help Desk and Troubleshooting: TENA Issue Tracking System
  - OM Design Support: MagicDraw UML-to-TDL Plugin
  - Legacy Test Asset Integration: TENA Adaptor
  - Test Event Management: TENA Console
  - 3D Visualization: SIMDIS TENA Plug-in
  - Video Sharing: TENA Video Distribution System
  - Data Logging: TENA Data Collection System
TENA enables JPARC to provide force-on-force (FOF) training capability that fully integrates and supports joint and coalition components for both air and ground training in live, virtual, and constructive (LVC) domains.

“TENA is the greatest thing that ever happened to us. We couldn’t be doing today with all these systems—and we couldn’t have all the participants that we do—if it weren’t for TENA”

Billy D. Smith
Chief of electronic combat training requirements for Red Flag at JPARC
● Data Collector
  ● Using TENA object models, data collection software is automatically generated to record object and message attribute values in a persistent data store (currently SQLite and MySQL database representations)
  ● Plan to provide add-on collection capability to allow publisher side collection, as well as subscriber side collection – which requires collection management capabilities

● Data Analysis Support
  ● Extractor tool provided to convert data into format that can be used by Microsoft Excel
  ● Analysis capabilities and tools are often highly specialized, and the intent of TENA is to provide a framework for user community to extend to support their unique data storage and analysis needs

● Data Playback
  ● Automatically generated playback tool can be used to re-play collected data for various forms of testing and analysis
Summary: Benefits of TENA

- TENA represents an enormous amount of practical experience focused on addressing common range infrastructure requirements
  - More than 8,000 registered users who have contributed to making TENA support their needs
  - More than 170,000 user downloads of middleware and object models used across the range community

- TENA’s technical approach emphasizes cost savings and reliability
  - The TENA software is hard to use wrong
  - TENA catches many user errors at compile time rather than run time
  - TENA tools provide unprecedented understanding of a distributed event

- TENA auto-code generation capability simplifies the creation of quality range infrastructure code
  - Auto-generated example applications mean you never start with a blank page
  - TIDE tool manages installation/configuration, upgrades, and maintenance
  - Rapid development of real-time, distributed, LVC applications
  - Auto-generated test programs make integration a snap

- TENA has many standard object models enhancing interoperability
  - Building blocks already exist for common data structures and algorithms
  - More than 750 user object models exist in the TENA Repository for reusability

- All TENA software and support is free to users
  - TENA is the most capable and sophisticated interoperability solution for the range community
  - TENA software is thoroughly tested and very reliable
  - The TENA web site/repository has extensive documentation, training, and collaboration capabilities

- TENA has a plan for continued evolution and funding to execute this plan!