Test and Training Enabling Architecture (TENA) in Cyber Test & Evaluation

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TRMC Supports Live Virtual Constructive (LVC) Test & Evaluation (T&E)

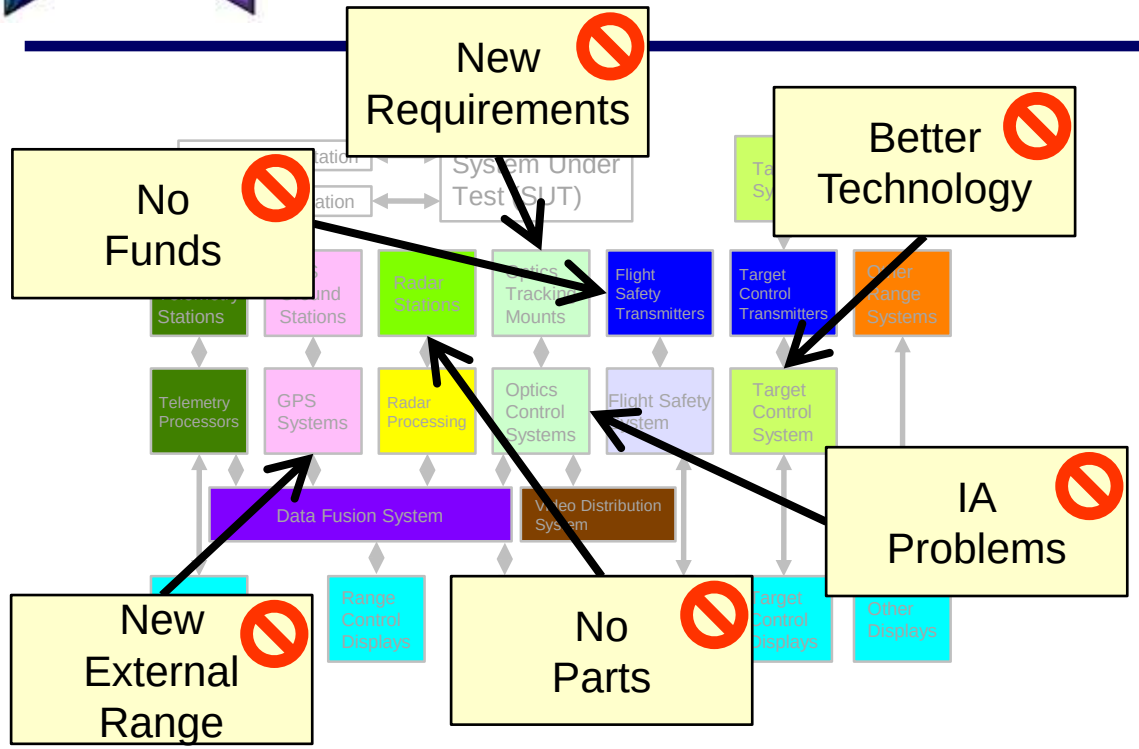
TRMC maintains an implemented architecture and network for Red and Blue Live Virtual Constructive (LVC) T&E:

- Mature, continuously improved software architecture (15+ years)
- Mature, continuously improved network infrastructure (8+ years)
- Standard interface definitions for integrating Red and Blue systems

Sampling of assets available via JMETC Network

- Proven tools suite to rapidly integrate and operate LVC-DE
- Existing TRMC subject matter expertise
- Integration of cyberspace T&E via National Cyber Range (NCR)
- Architecture enables integration of emerging Red/Blue capabilities
- Used to support over 250 distributed test events since 2007

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 ranges

Test and Training Enabling Architecture (TENA) at a Glance

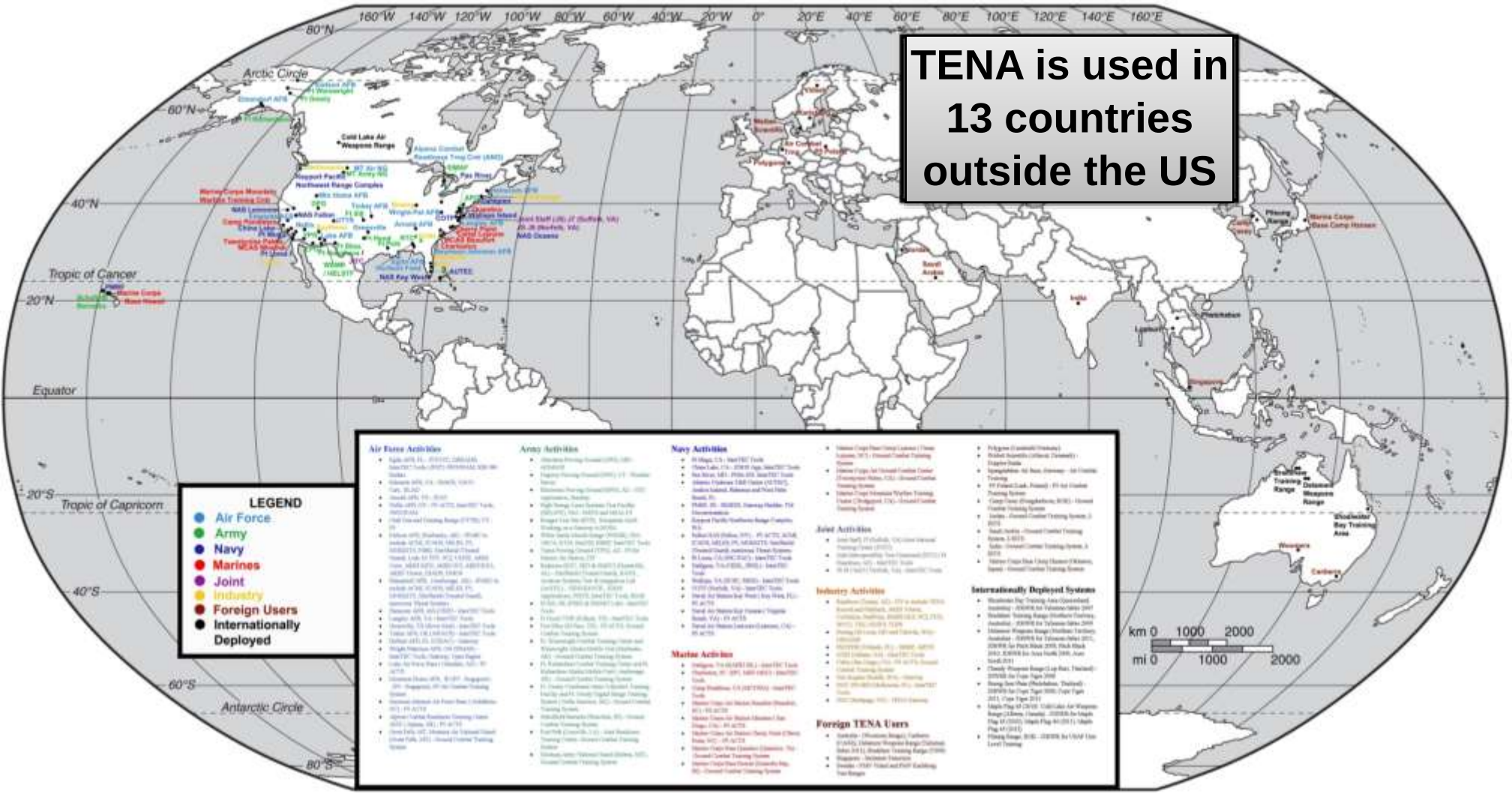
TENA is DoD's GOTS range integration architecture

- **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

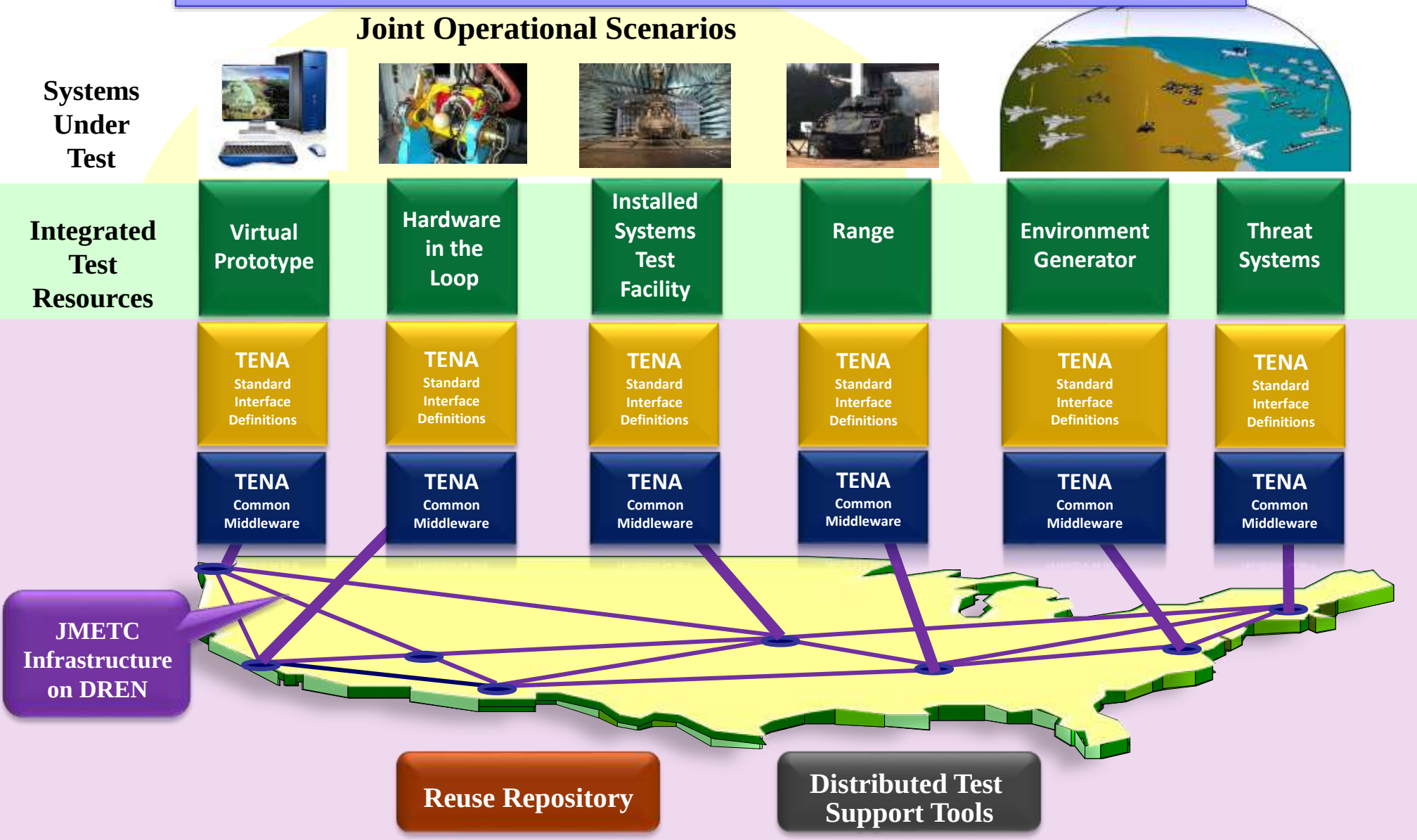
- **TENA has a plan for continued evolution and funding to execute this plan**

Worldwide Use of TENA



JMETC
Distributed Test Architecture

JMETC depends on TENA to support distributed testing



* TENA: Test and Training Enabling Architecture

TENA is an Open and Evolving Architecture

- **Software Engineering Institute (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 Models are publicly available and downloadable without restriction
    - Range system interface standards developed with community to support remote monitoring and control from a vendor agnostic manner
    - Users can create, modify, or extend object models for a given organization or event to satisfy unique distributed communication interface requirements
- **TENA Products evolved in response to range needs and technology changes**
  - TENA software products continue to evaluate and use open source software – ACE/TAO, Boost, Qt, SEDRIS, and others
  - Government owned, without any proprietary software
  - Source code collaboration services supported for various products
  - Standard interfaces emphasized to enable implementation technology changes

Architecture Management Team (TENA AMT)

- **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

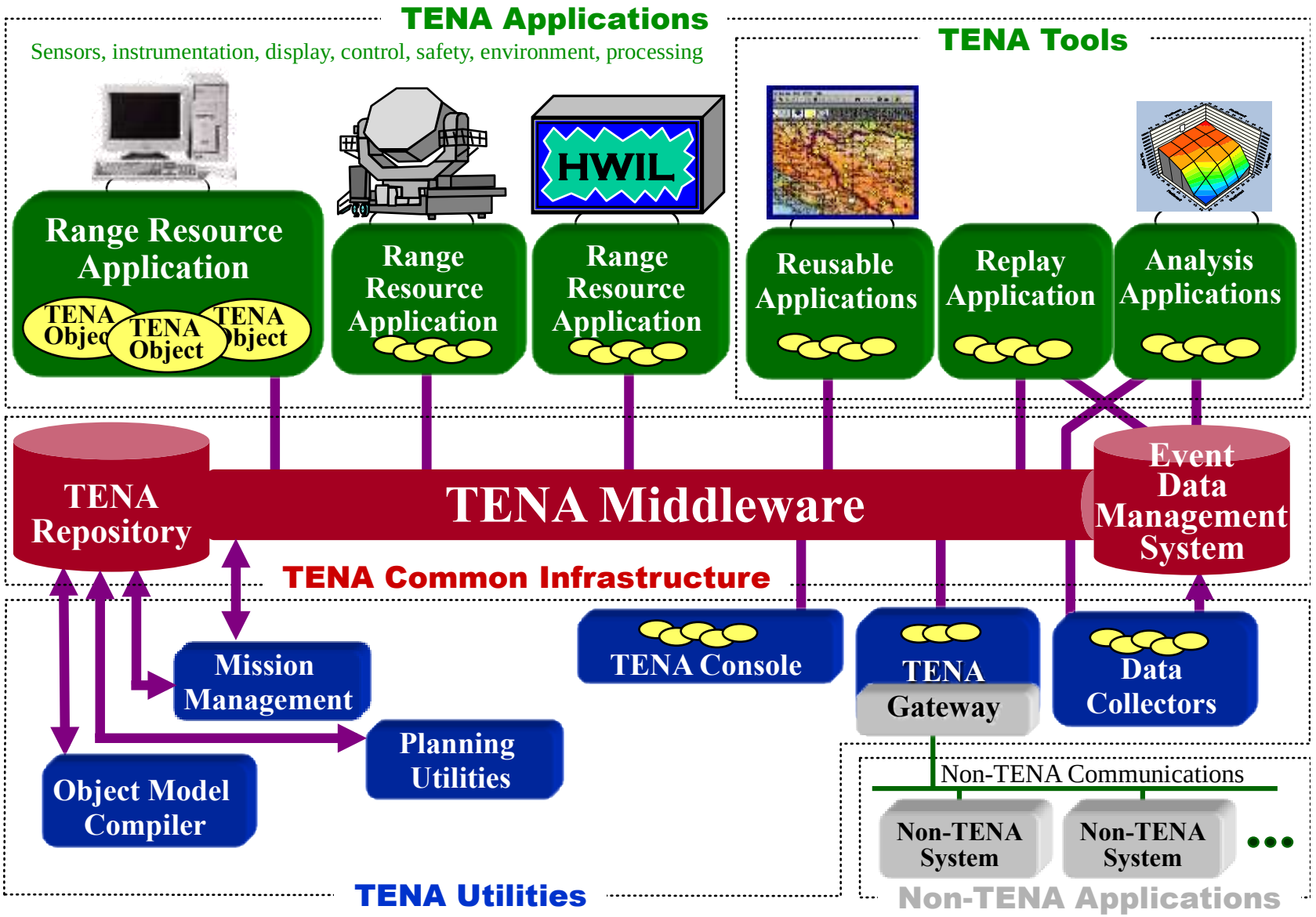
- **Boeing**
- **Cubic Defense**
- **DRS**
- **Embedded Planet**
- **EMC**
- **General Dynamics – C4 Systems**
- **Kenetics**
- **MAK Technologies**
- **NetAcquire**
- **Raytheon**
- **Science Applications International Corp (SAIC)**
- **Scientific Research Corporation (SRC)**
- **Scientific Solutions,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

International Participation

- **Australia**
- **Denmark**
- **France**
- **Singapore**
- **Sweden**
- **United Kingdom**

- **Design Decisions / Trade-offs / Status / Technical Exchanges of Lessons Learned / Use Cases / Testing / Issues & Concerns Identification, Investigation & Resolution**

TENA Architecture



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 SDA is working with IA organizations to reduce event cost and delays through certified TENA software

TENA Object Models

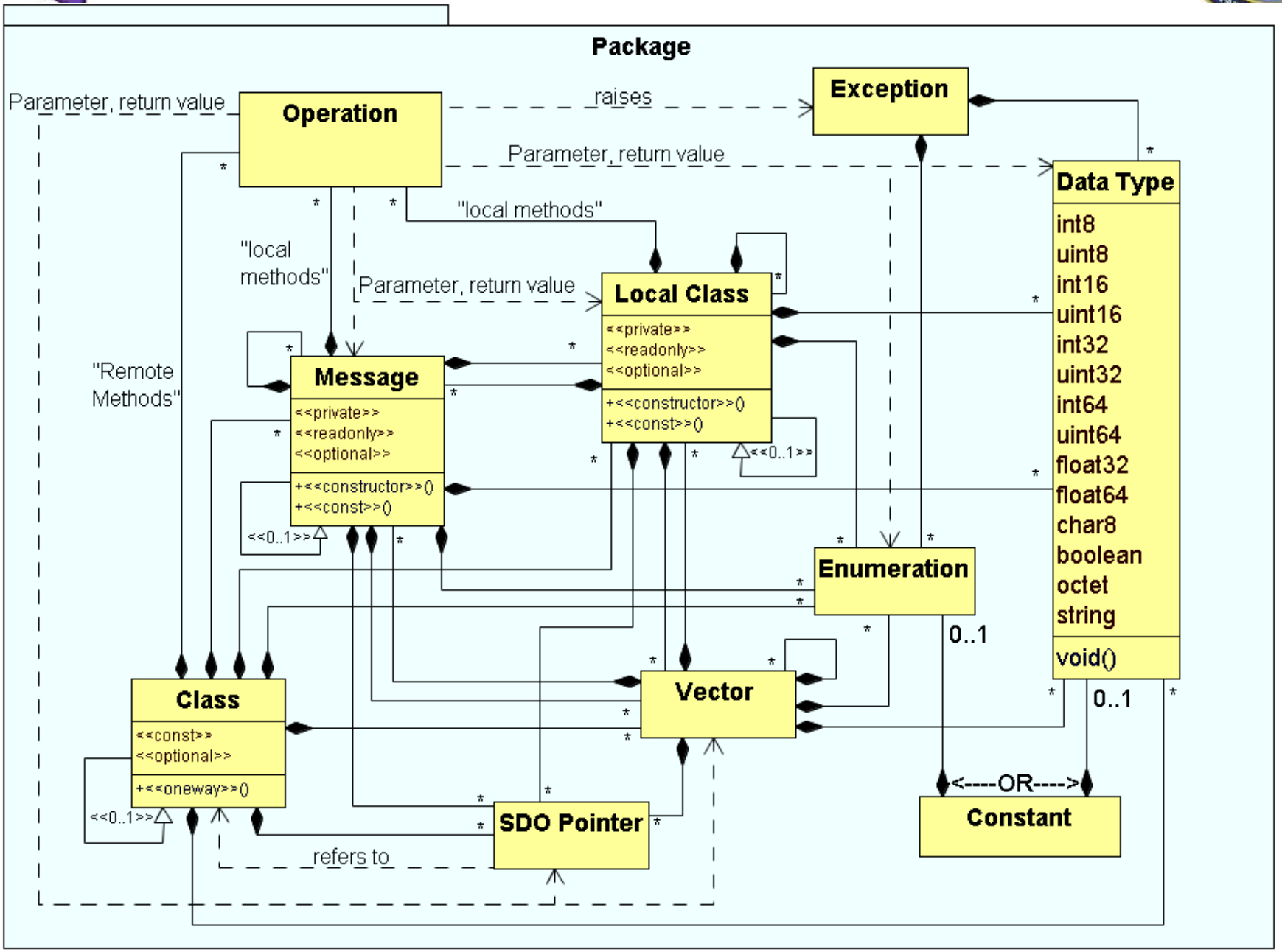
- **TENA uses Object Models to define system interfaces**
  - Used to formally define the data and method interfaces of a range system
  - Rich meta-model available with automatic code generation of properly designed, tested, and IA scanned software code to support common range system needs
  - Object models are properly versioned and support specialization when needed
- **TENA SDA provides Repository for Object Model definitions created by the user community to promote interoperability and reuse**
  - Provides the authoritative source and archive for range system interfaces
  - Website used to generate interface dependent software for various capabilities across 50+ different computer platform configurations used by range community

TENA Object Models provide a common external interface for your system

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 Release 6 Metamodel



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

Data Management

- Local and Remote Command and Control
- Health & Status Monitoring

Event Management

- Real-Time simulations
- Stimulation of live sensors and instrumentation
- Connecting non-interoperable inter- and intra-range systems

LVC Integration

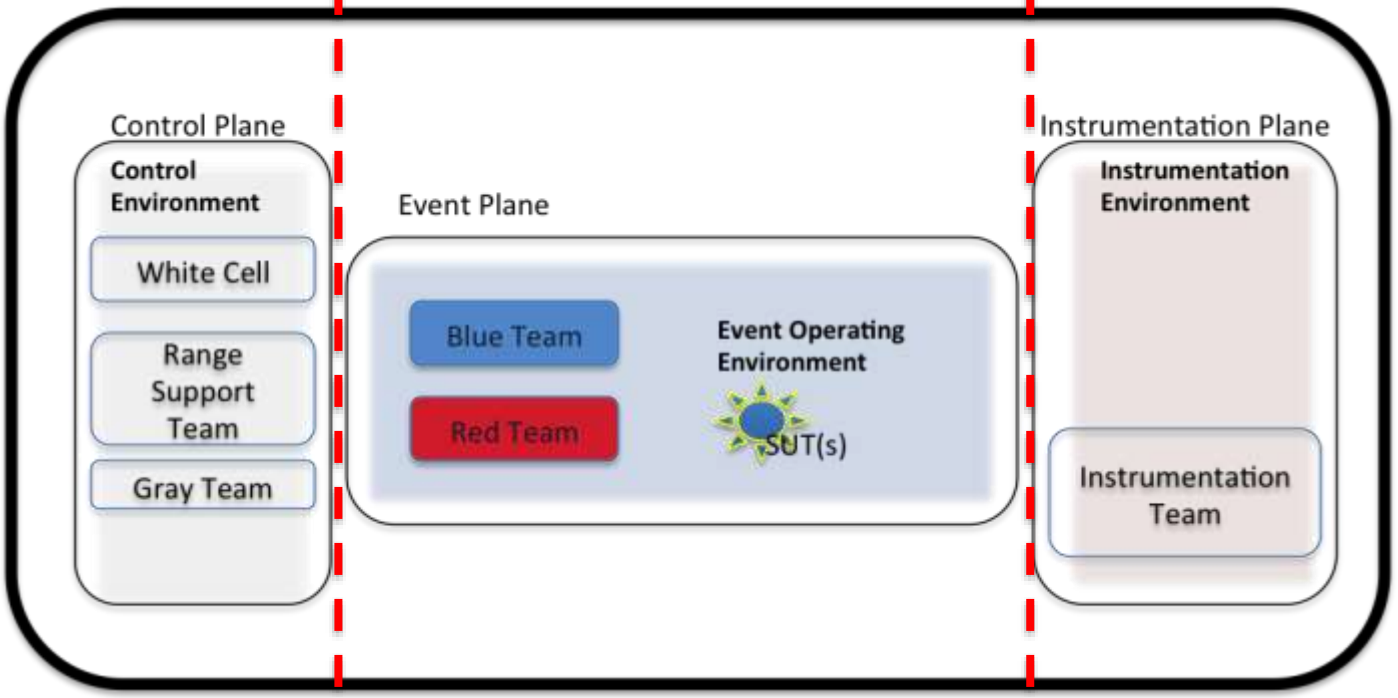
- Eliminating proprietary interfaces to range instrumentation
- Sharing and reuse of common range tools and capabilities
- Online Collaboration and File Sharing

Sharing & Reuse

These activities are all relevant to cyber experiments

Cyber Event Considerations

Challenge: How do we reduce development and integration schedule / cost / risk?



Solution:

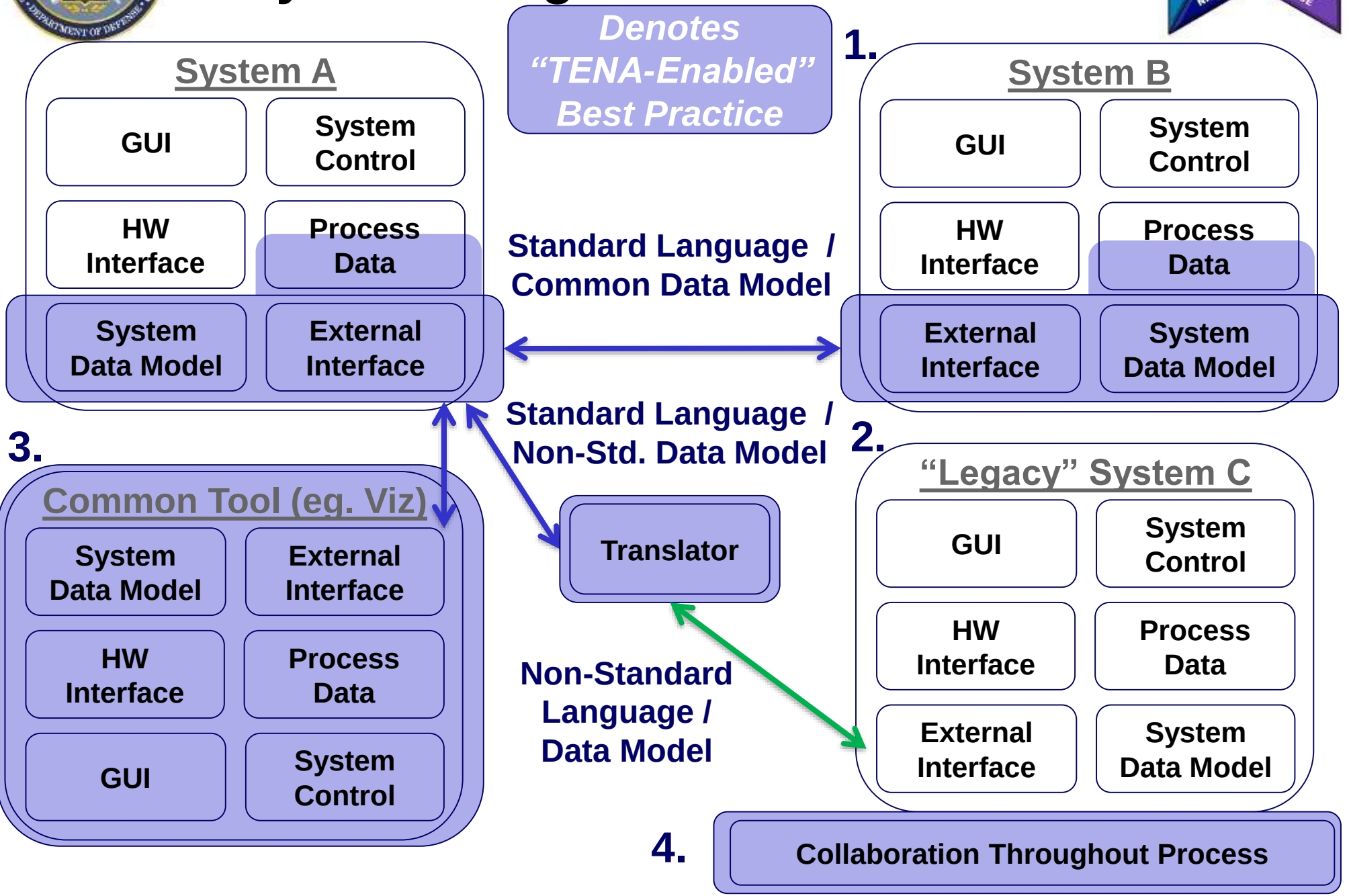
TENA Communication & Tools

"Tactical" Traffic

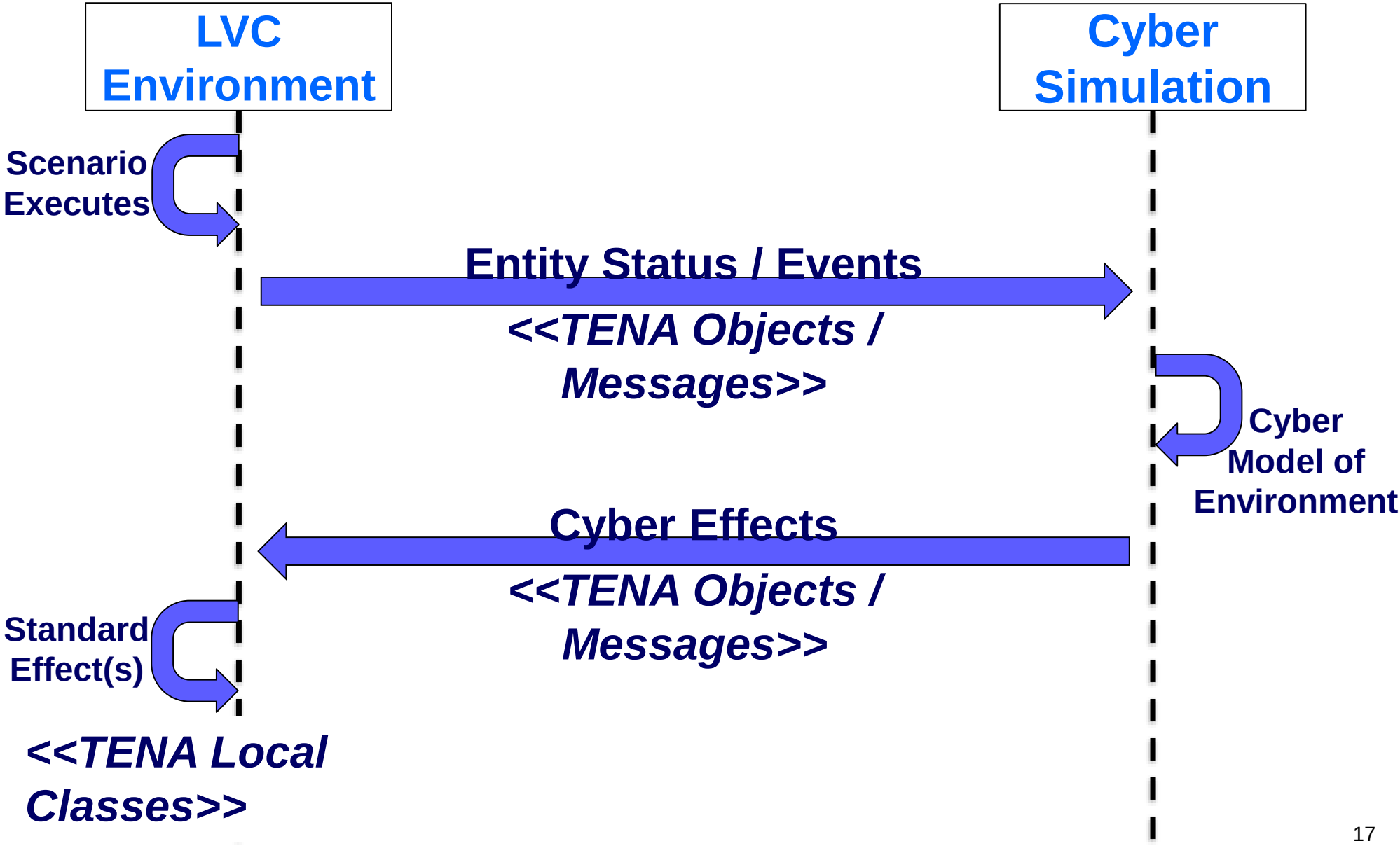
TENA Communication & Tools

From CRIS WG Event Interoperability Fundamentals for Cyber--Range Tools and Processes

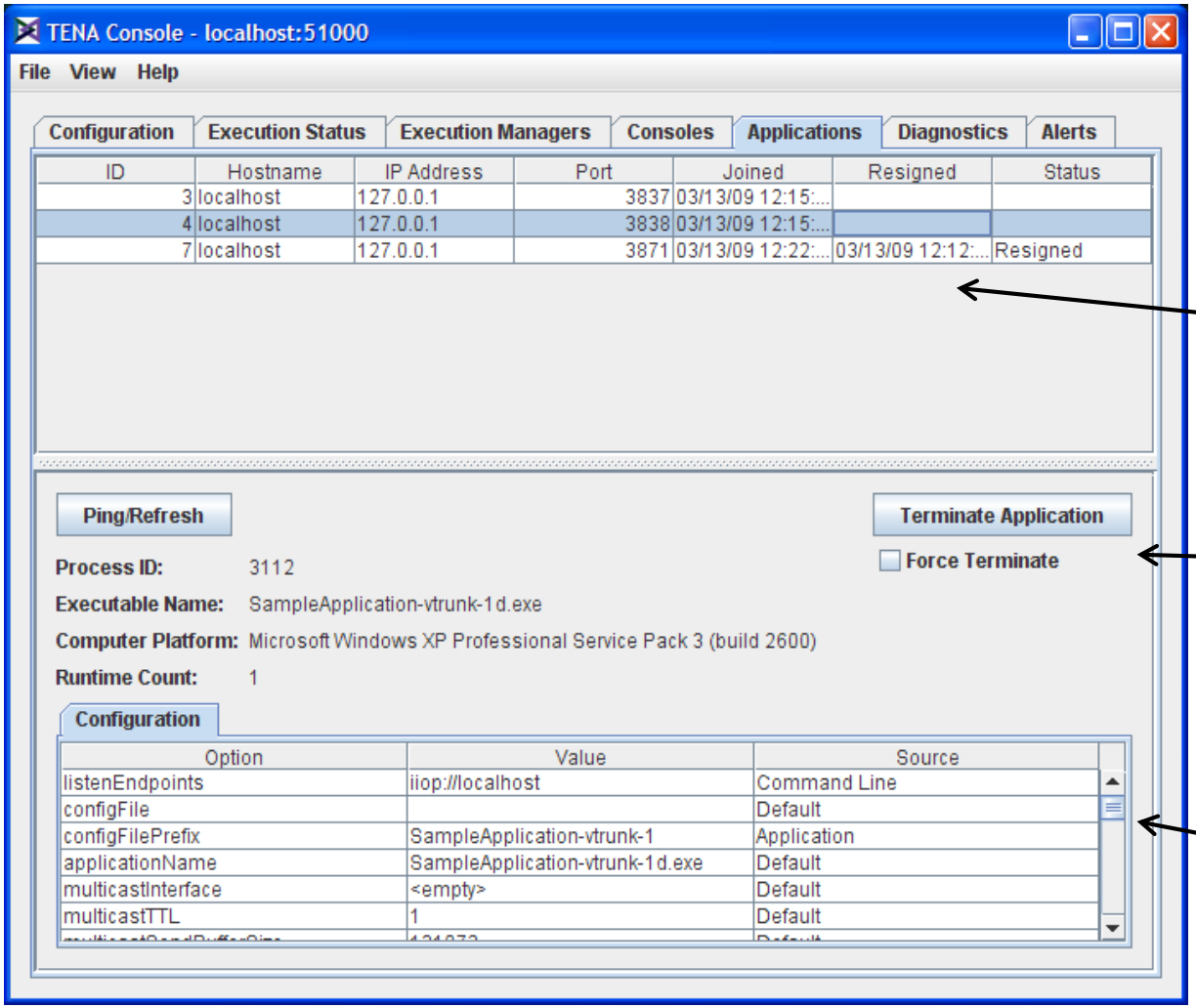
Mitigating Challenges: Select System Integration Best Practices



Design Example: Cyber Simulation Integration with LVC Environment



TENA Console
Remote Application Configuration and Operating Parameters



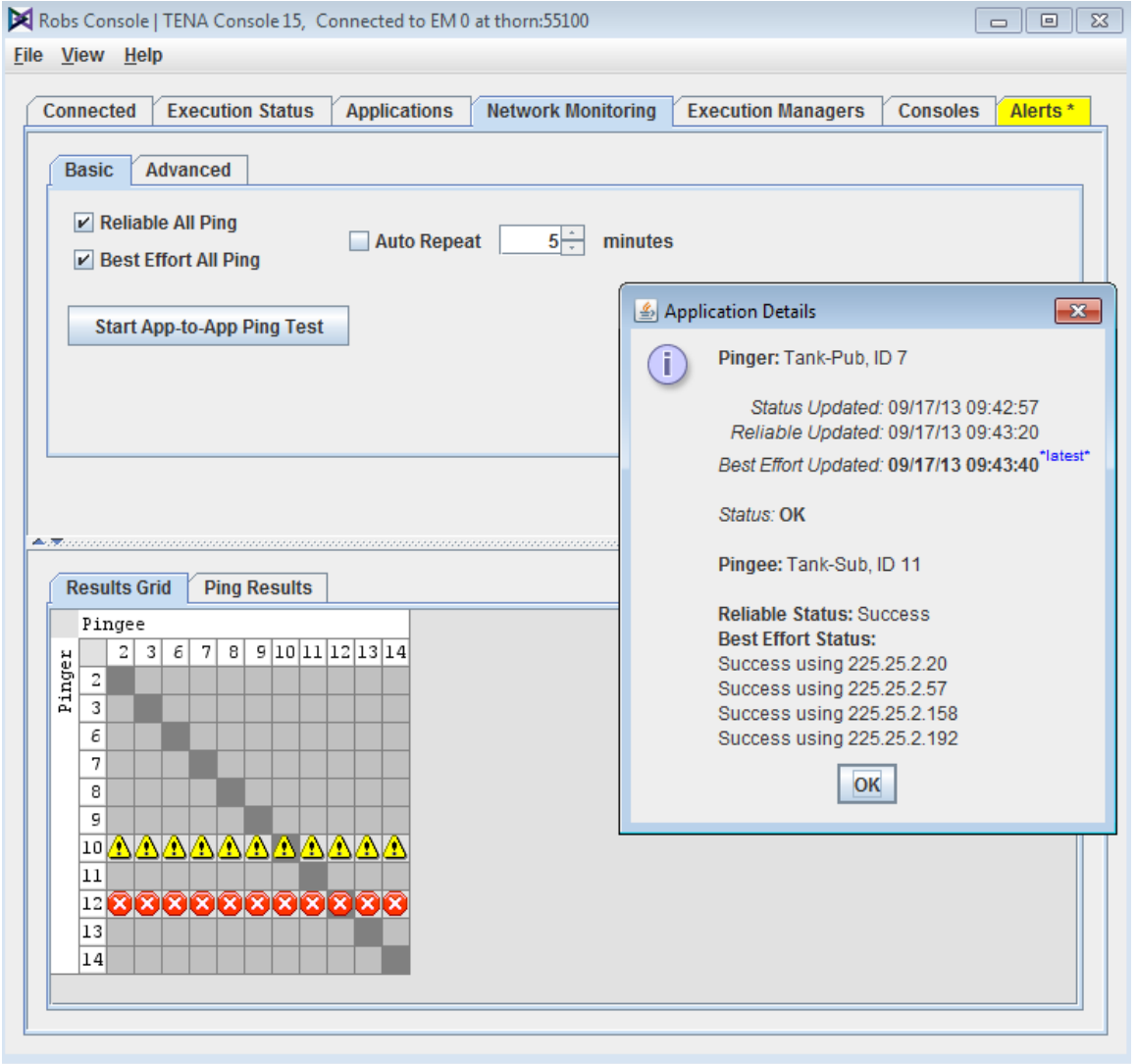
Basic application information provided in table

"unresponsive" applications can be terminated

Application configuration parameters listed to indicate use of non-default values

TENA Console Network Monitoring

- **Event Management Tool**
  - Examine configuration parameter values
  - Monitor middleware diagnostics for each system
  - Perform continuous TCP and UDP multicast communication monitoring
  - Obtain system alerts regarding the operation of the distributed event



TENA Upgrade Support Offer

- **The TENA team is available to offer advice and assist any organization looking to use TENA**
  - Advice on overall design approach and trade-offs to consider
  - Recommended Object Models to reuse
  - Recommendations on how to design new Object Models
  - Implementation / Code Designs Reviews
  - Awareness of similar systems and lessons learned
  - Hands-on training classes on TENA capabilities
  - Contract language to help ensure TENA-enabled solutions

Opportunity to Get Assistance in Using TENA

E-mail request to: feedback@tena-sda.org

TENA Is…

- An implemented architecture that reduces integration time and cost
- A suite of software and best practices matured over 15+ years
- 100% Government off the Shelf (GOTS)
- Free tools for common Event Planning, Execution, and Analysis functions
- Auto-code generated for 34 operating system / compiler combinations and C++ / Java / .NET programming languages
- Leverages, but does not require, use of data standards
- Includes support for other transport protocols in its architecture
- Institutionally Resourced and Sustained
- Constantly improved to meet new user requirements
- Subject Matter Experts for distributed exercise and system integration

Important Contact Information

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

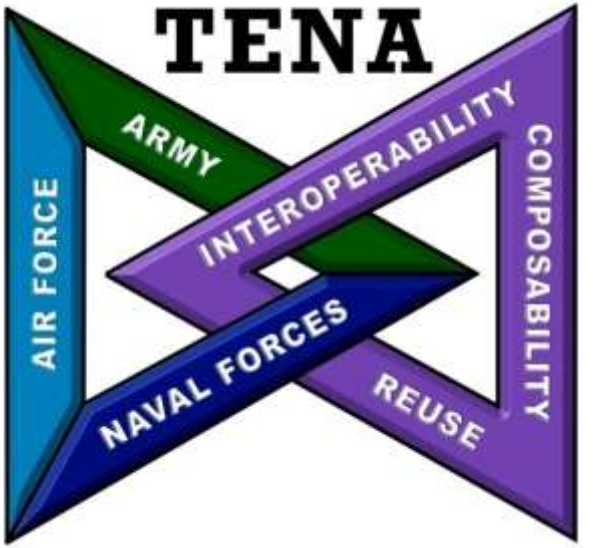
- **TENA Feedback: feedback@tena-sda.org**
  - Provide technical feedback on TENA Architecture or Middleware
  - Ask non-technical questions regarding TENA
  - Provide responses to AMT action items
  - Request TENA training

Summary

- **Capabilities and Lessons Learned from kinetic test & training apply to Cyberspace test & training problems (and vice versa). Uniform Needs:**
  - Reduce setup and integration time
  - Government-maintained interfaces to capabilities
  - Gradual migration of existing capabilities to standards compliance
  - Extensive library of applications and source code available for reuse

- **The Test and Training Enabling Architecture (TENA) is helping standardize integration of range systems for efficient T&E and training**
  - US 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

Backup Slides



TENA Mission

- Historically, range systems tend to be developed in isolation, focused on narrow requirements, and constrained by aging techniques/technologies
- Range infrastructures have grown organically with minimal coordination or sharing, resulting in duplicated effort and many "stove-pipe" systems

The purpose of TENA is to provide the necessary enterprise-wide architecture and the common software infrastructure to:

- **Enable interoperability among range, C4ISR, and simulation systems used across ranges, HWIL facilities, and development laboratories**
- **Leverage range infrastructure investments across the DoD to keep pace with test and training range requirements**
- **Foster reuse of range assets and reduce cost of future developments**

Working with the Range Community to Build the Foundation for Future Test and Training Range Infrastructure

Where TENA is Used

- **<u>Any</u> 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 <u>not</u> intended to replace messaging formats used in theater operations**
  - Examples: LINK-16, Variable Messaging Format

Benefits of TENA

- **All TENA software and support is free to users**
- **TENA is the most capable and sophisticated interoperability solution**
- **TENA software is thoroughly tested and very reliable**
- **TENA Auto-Code Generation makes creating a TENA application as simple as possible**
  - TIDE Tool manages installation and configuration, upgrading and maintenance
  - Auto-generated starting points mean you never start with a blank page
  - **Rapid development** of real-time, distributed, LVC applications
  - Auto-generated test programs make integration a snap
- **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 an event
- **TENA has a standard object model enhancing interoperability**
- **The TENA web site/repository has extensive documentation, training, and collaboration capabilities**
- **TENA has a plan for evolution and funding to execute this plan!**

What Makes TENA Effective?
Core Architectural Tenets

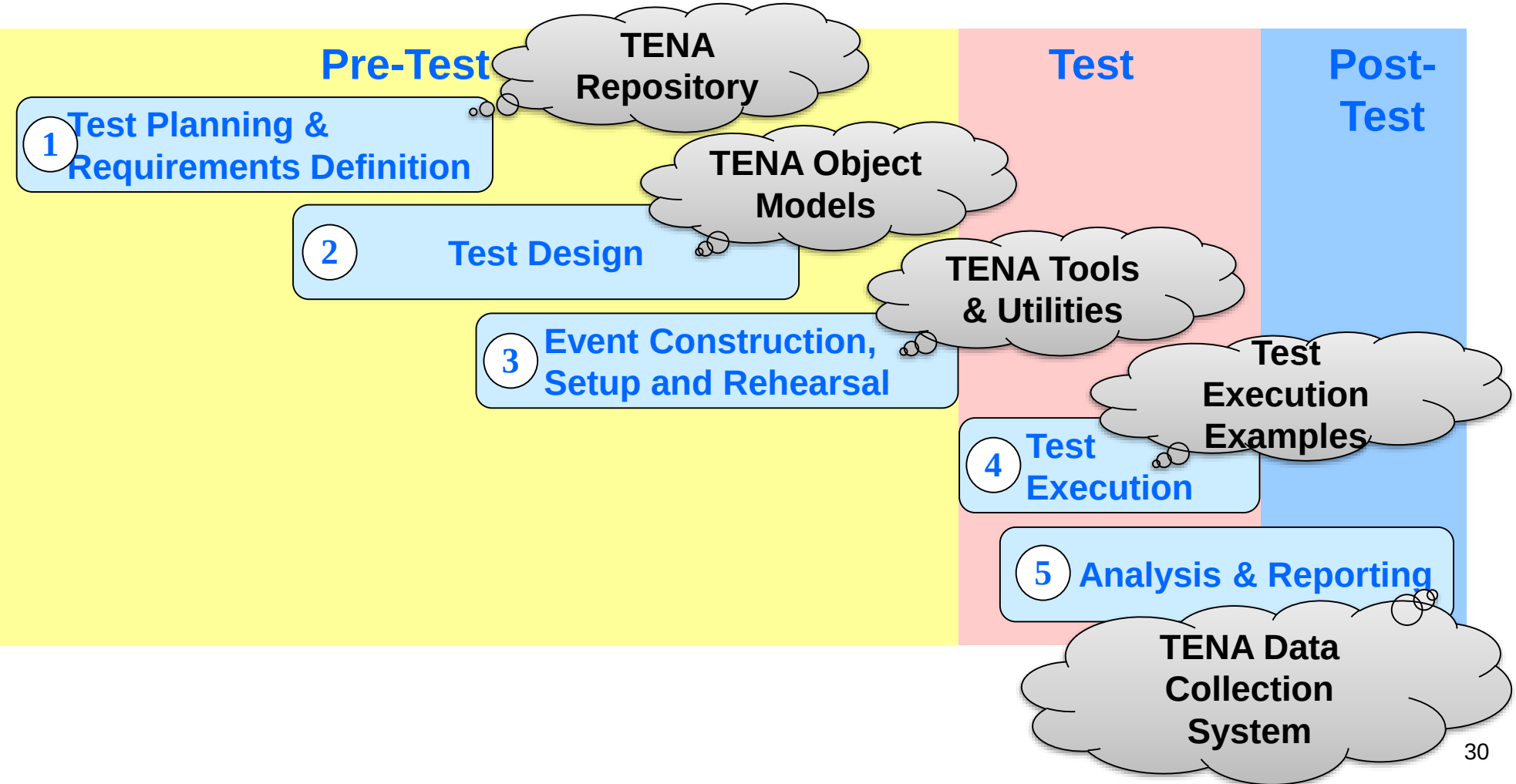
- **Promote Computer Enforceable System Interfaces**
  - For meaningful interoperability, systems should formally define their interfaces for the particular data produced or consumed and the services/algorithms provided or required
  - Generic interfaces may look appealing, but significant costs exist 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

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

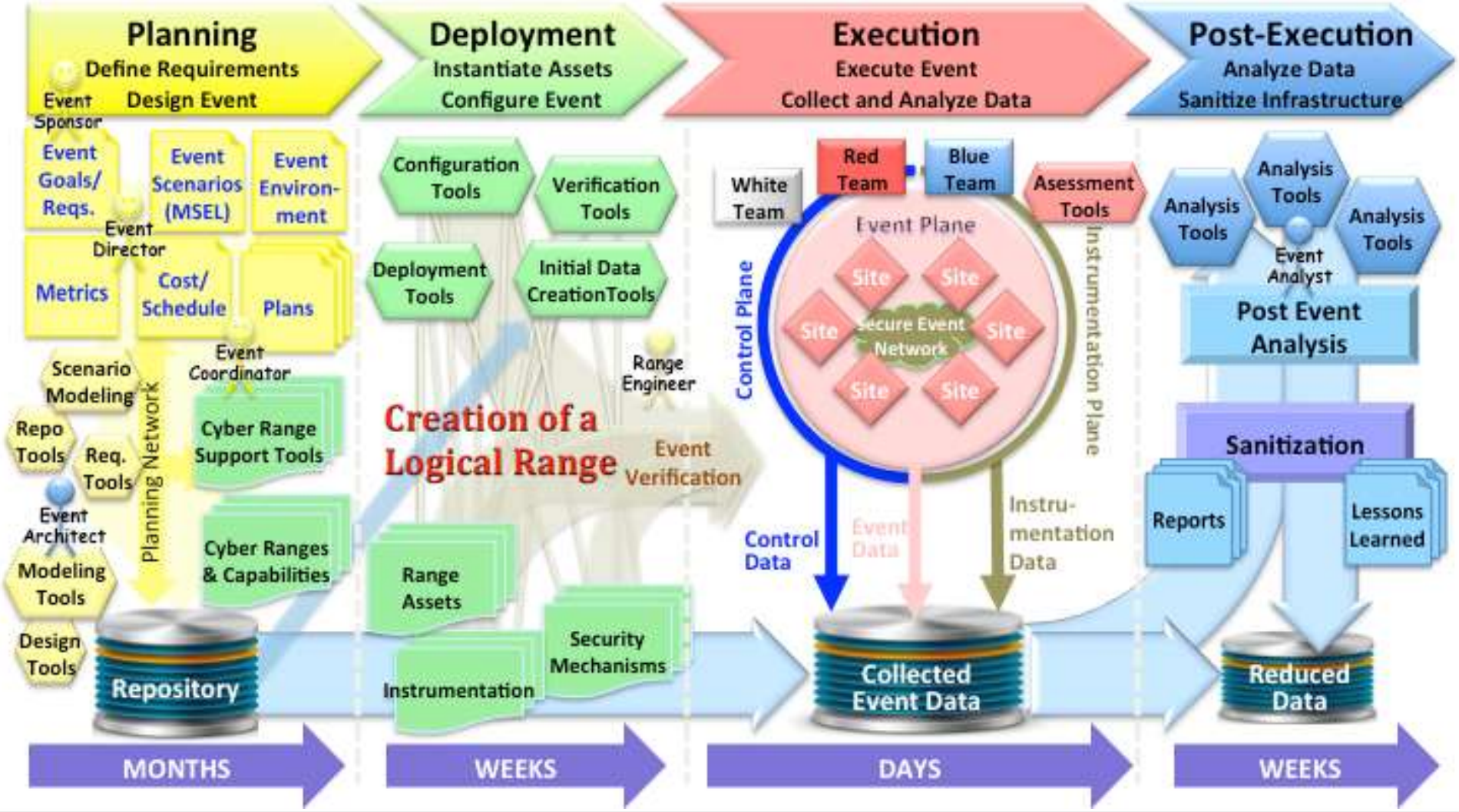
How TENA Supports T&E: Notional Event Walkthrough

TENA enables efficiencies through inherent interoperability and reuse



Look Familiar?

CRIS WG Cyber Range Event Process



We can leverage "traditional" exercise capabilities in cyber exercises and vice versa

Test Planning: TENA Website Services
https://www.trmc.osd.mil
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

TENA Software Repository

Currently supporting 40 computer platforms

1,198 different object models

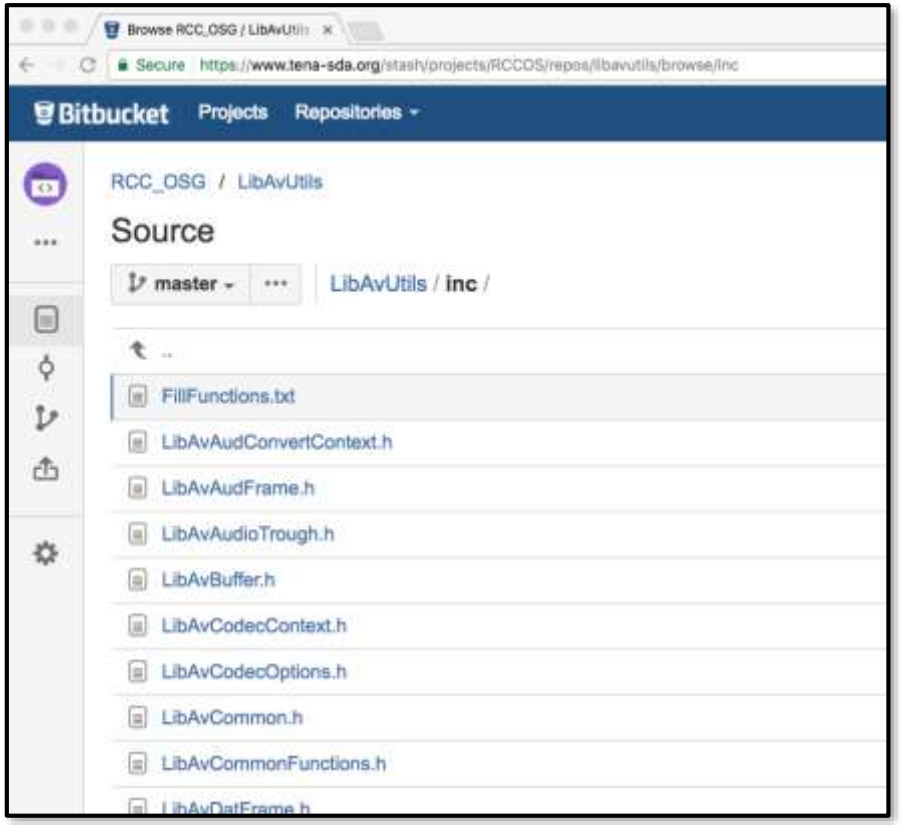
Repository software downloads of 2,877 in 2014

727 middleware development kits downloaded in 2014

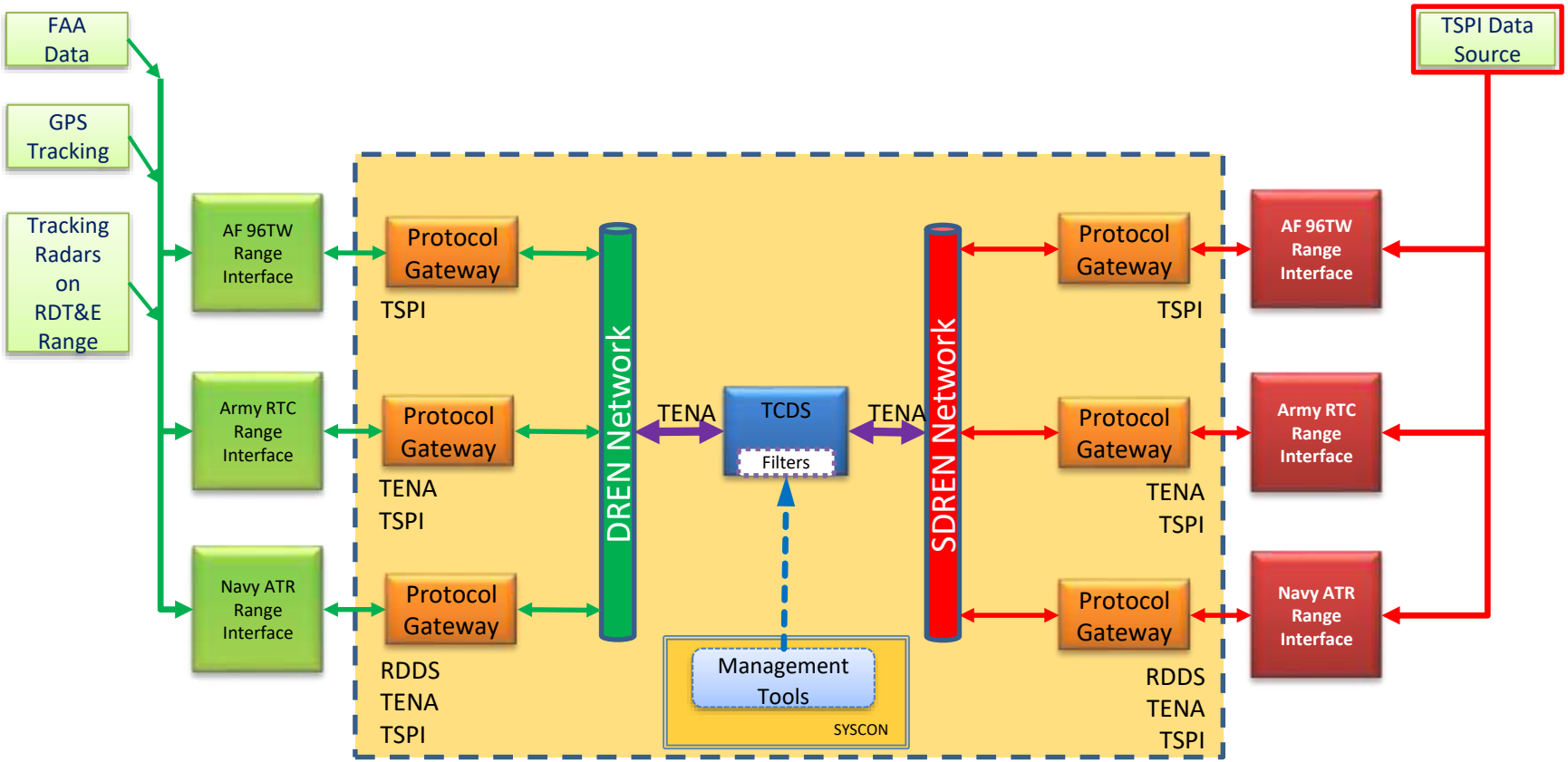
TENA Website (wiki and helpdesk)

Planning Support: TRMC Code Collaboration Website Service

- **Code Collaboration**
  - User Groups can share source and binary code using Git Repositories
  - Git is a popular configuration management system for code collaboration
  - Developers can use web-based interface to view code, as well as command line operations that interface with the Git server
- **Access Controls**
  - Access to the code are controlled by the User Group administrators
- **Usage**
  - Pilot project started with Range Commanders Council Optics Systems Group and White Sands Missile Range, but has expanded to other groups
  - Provides ability to support distributed development for range systems and tools



Test Design Example: MLS-JCNE CDS System Design Diagram



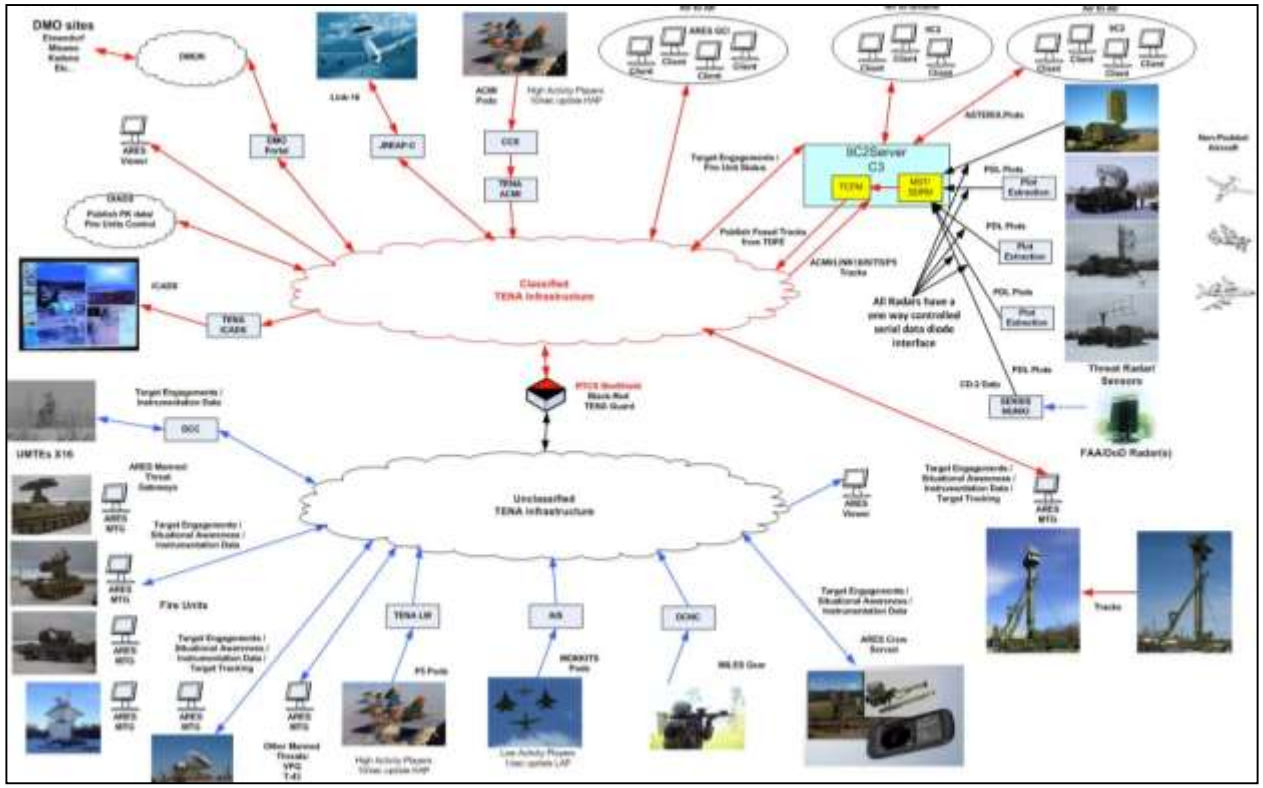
The Goal of the Block 1 MLS-JCNE implementation is to provide the RDT&E community with a persistent, interoperable, and reusable capability to exchange unclassified data between unclassified and classified enclaves

Test Construction/Setup: TENA GOTS Tools (Partial List)

- **TENA Utilities—Making TENA easier to use**
  - TENA Repository (automated software building, community source code collaboration)
  - TENA Wiki (website collaboration for user groups)
  - TENA Issue Tracking System (task tracking system for user groups)
  - TENA Installer (cross platform software installation)
  - MagicDraw Plugin (converts UML diagrams in object model TDL syntax)
- **TENA Tools—Helping you conduct and manage your event**
  - TENA Middleware (C++, Java, .NET support for ~50 computer platforms)
  - TENA Console and Canary (event management and network monitoring)
  - ClearPath (multicast network testing)
  - TENA Data Collection System (collector, database export, and playback tools)
  - Interface Verification Tool (Platform generator to support testing activities)
  - Web Binding (provides JSON/REST http interface to TENA systems)
  - RelayNode (bridges different communication domains)
  - SIMDIS TENA Plugin (3D visualization and analysis support for TENA object models)
  - TENA Video Distribution System (various tools related to video/audio stream support)
  - Mission Information Resource Controller (automated configuration for distributed systems)
  - Network Communication Tools (chat, file transfer, etc.)
  - SimShield Trusted Guard (Cross Domain Solution supporting many object models)

Test Execution Example: Joint Pacific Alaska Range Complex (JPARC)

- **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

Test Analysis / Reporting: Data Collection and Analysis Framework

- **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